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Component Geographic Factors of the Natural Regions of Burma

HELLMUT DE TERRA*

The Burma Road with all its strategic and political implications has focused attention on a monsoon country of which relatively little is known but which deserves a much greater measure of interest than has hitherto been accorded it. From a geographic point of view, Burma offers a wealth of interesting information pertaining to major geographic and geologic phenomena in Asia, as for instance, the concerted interplay of physiographic, climatic and anthropologic factors in the shaping of its natural regions. The component landscape factors are, in the case of Burma, so clearly expressed as to provoke an immediate desire for a more detailed study. The greatest obstacle to fulfillment of such a desire is of course paucity of reliable observations dealing with geographic and anthropologic subjects. But, because of my own brief acquaintance with Burma, such an attempt would seem to be warranted, especially at this time when the country plays such a vital role in the deployment of socio-political forces in Southeastern Asia.

My own observations in Burma were somewhat limited in scope by the special tasks which I felt called upon to pursue as director of the Southeast Asiatic Expedition of 1937–1938.[1] Now that the results of these investiga-

* Dr. de Terra is the author of several publications dealing with geographical and geological aspects of southern Asia, especially northern India, the Himalaya Mountains and Tibet. He is now Chief of the Regional Research Section, United States Board on Geographical Names, Department of the Interior.

[1] H. de Terra and H. L. Movius: Research on Early Man in Burma. *Transactions of the American Philosophical Society*, New Series, Vol. 32, Part III, pp. 265–464, Philadelphia, 1943.

tions have been published, it seemed to me desirable to make use of certain other data which I had collected, partly by observation in the field and partly by subsequent map studies. These observations on climate and vegetation, and on certain human factors held to be influenced by them, would by themselves not have sufficed for a regional geographic study of this sort, so I had to supplement them with information derived from the few existing authoritative books on Burma. The publications by Dudley L. Stamp, H. L. Chhibber, and by members of the Geological Survey of India and of the Indian (Burma) Civil Service have been of great help.[2] The maps on rainfall are based on the official data of the Meteorological Service of Burma as well as on rain gauge readings obtained from private sources during my visit. The vegetation map with all its incompleteness is a compilation from various sources, including my own observations. It differs in many respects from the one presented some 20 years ago by L. D. Stamp.

Great care was given to the treatment of the racial map. It is based on a meticulous plotting of tribal names appearing on the more recent topographic sheets of the Survey of India Series, which information was supplemented by the data of the official Census Report of 1931 and by others found scattered in travel literature. In this and other instances, I have tried my best to discriminate between the authoritative and the casual descriptions and have generally found few that could be relied upon. On the whole, the literature on Burma is woefully short of such authoritative treatises as deal with the neighboring lands of Thailand and Indochina. In a sense it is an unexplored country, and if this account can help to stimulate progress in this direction it will have fulfilled its purpose.

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[2] Dudley L. Stamp: *Asia, a Regional and Economic Geography*, E. P. Dutton & Co., New York, 1938, pp. 341–365; Burma, an Undeveloped Monsoon Country, *Geographical Review*, Vol. XX (1930), pp. 86–109. H. L. Chhibber: *The Geology of Burma*, MacMillan and Co., London, 1934. G. E. Pilgrim: The Tertiary Formations of India, *Proc. Pan-Pacific Sci. Congress*, 1923, pp. 896–931. G. de P. Cotter: The Geotectonics of the Irrawaddy Basin, *Jour. Proc. Asiatic Soc. Bengal*, Vol. XIV (1918), pp. 409–420. E. L. C. Clegg: The Geology of the Minbu and Thayetmyo Districts, Burma, *Mem. Geol. Surv. India*, Vol. LXXII (1938), pp. 137–317. E. H. Colbert: Siwalik Mammals in the American Museum of Natural History, *Trans. Amer. Phil. Soc.*, Vol. XXVI, 1935, pp. 1–401.

THE PHYSIOGRAPHIC PLAN

Few regions in the world own such a simple orographic structure as Burma, and fewer still portray as plastically the dependencies of human living on the physiographic ground plan (Fig. 1).[3]

Three major physiographic divisions may be recognized: the *Irrawaddy Basin,* extending over a distance of some 875 miles, from the foot of the Tibetan Plateau to the mouths of the Irrawaddy River; a *mountain frame* comprising the Western Mountain Belt, the Meridianal Watershed Ranges in the north and the Shan Highlands to the east; the *Tenasserim Coast Ranges* in the south extending from the Salween outlet to the Isthmus of Kra. The orographic alignment of these major units is from north to south, with the Western Moutain Belt forming a convex arch turned toward the Ganges Delta.

The Mountain Frame. The relief culminates in the north where an unnamed mountain massif north of Putao (P on Fig. 2) rises to over 19,000 feet. In this region lies the famous re-entrant of the Himalayas whose structural axis bends at right angles into a north to south strike. Small glaciers are the sources for the great tropical Irrawaddy River, and moraines descend to 9,000 feet. The snowline is at 20,000 feet, but snow beds block the higher valleys until mid-summer. Southward, the relief unit above 6,000 feet extends over both the western and the eastern mountain frame, and it sends high interstream divides into the center of the basin. In the west it is deeply dissected by a system of north-to-south-flowing streams which follow the geologic structure. Between the Patkoi Range and the Arakan Yoma is found an area of lower relief known as the "Highland of Manipur" (Fig. 1, "I"). Here an intermontane basin at 2,500 feet and a subdued relief at about 5,000 feet form a sort of breach through which peoples have migrated to Burma at intervals. Judging from the few descriptions available, it would seem as if that area is a composite type of relief in which at least two different older erosion cycles are indicated. Concordance of summit elevations, level surfaces and basining are characteristic both of the Highland of Manipur and of the Patkoi Range (Fig. 2). No doubt these older land surfaces belong to cycles of stream action which antedate the vigorous phase of vertical erosion that is responsible for the rugged topography of the Western Mountain Belt. How old are these subdued relief units and whence dates the rejuvenation of the relief? The answer may perhaps be found in the records of past stream actions as deduced from the basin sediments of Cenozoic age. Judging from the composition of the sediments on the eastern flank of the Arakan Yoma, I have suggested in my

[3] For a general introduction to the physiography of Burma see H. L. Chhibber, *The Physiography of Burma,* London, 1933.

monograph (footnote 1) that there are two major unconformities in the Irrawaddy series. One is the break between the Lower and the Upper Irrawaddy beds, and the other is the unconformity between folded Upper Irrawaddy and Middle Pleistocene stream deposits. These structural breaks conform strikingly with the two most recent phases of sharp upward crustal movement in the Himalayan region, as I have already pointed out elsewhere (De Terra and Movius, *op. cit.*, p. 331). In view of the general structural affinities between the Arakan Yoma and the southern Himalayan Ranges, I surmise that the sharp dissection of the western relief in Burma is the result of late Pliocene and Quaternary uplifts. The remnants of a subdued relief, on the other hand, seem to me datable by these phases of basin sedimentation, which by virtue of their silt and clay content reflect an upland of low-angle slopes and leisurely stream work. Such a hilly upland no doubt was the source for the silt and fine grained beds of the "Lower" Irrawaddian beds, which G. E. Pilgrim[2] dated as Lower Pliocene. Geological records indicate that the Western Mountain Belt is part of the Himalayan system. Marine Mesozoic and some Paleozoic strata were tightly compressed into folds separated by thrust-faults in a manner suggestive of westward movement. There are no Mesozoic red beds or late Cenozoic basin formations such as characterize the landblock east of the Irrawaddy. Why then does the Western Mountain Belt not attain elevations comparable to those of the Himalayas? Two reasons suggest themselves. The Himalayan geosyncline was shallower in Burma, as is indicated by the relative thinness of marine Mesozoic beds, and, therefore, the folding as a whole was less pronounced. The other reason may be found in the peculiar structural position of the Western Mountain region in relation to neighboring geotectonic units. A promontory of the Indian landmass, now largely concealed by the Assam basin through younger collapse, projected into the geosyncline and protected, as it were, the Burman region from the successive onslaughts of crustal pressure from the north. Lying behind this promontory, the orogenic forces in our Burma region were weakened as in a dead corner, east of which lay a relatively stable landmass. This situation may also account for the presence of great Himalayan elevations northeast of the hypothetical promontory (Assam basin), in the Chinese-Tibetan borderland, for there was no obstacle to hinder the full employment of compression and of vertical uplift.

FIG. 1—Blockdiagrammatic sketch of central Burma. The scale is approximately 1 : 4,000,000. The two structural sections show simplified structures in which the Cenozoic formations are marked with dots and dashes respectively, conglomeratic strata with circles. The Mesozoic folded rock units to the west contrast with the contorted folds in Paleozoic metamorphosed rocks and intrusive granites underlying the Shan Highlands in the east. Railroads are marked by crossed lines.

INDIA
CHINA
THAILAND
90°
100°
20°
10°
UNITED STATES
DEPARTMENT OF THE INTERIOR
BOARD ON GEOGRAPHICAL NAMES
BLOCK DIAGRAMMATIC SKETCH
OF CENTRAL BURMA
By H. deTerra

FIG. 1

For this reason, traces of glaciation while lacking in the Arakan Yoma are found north of the 27th parallel, where the relief becomes steeper, and where glaciers, remnants of formerly more extensive glaciation, exist. Boulder gravels and morainic debris issue from the tributary valleys, suggestive of glacial outwash on a scale incommensurate with the present restricted glaciation.[4] Wissmann[5] quoted moraines from as low as 9,000 feet, and he computed a snowline depression of 3,600 feet for the last glaciation, stating that such a figure agrees remarkably with the snowline depression in the eastern Alps.

By comparison the Eastern Mountain frame presents a much more even surface, although altitudinal differences are sufficiently great to warrant preference for the term highland rather than plateau. On the Irrawaddy-Salween Divide, for instance east of Hsenwi, in the northern Shan States, sharply pointed peaks rise as high as 8,000 feet, and throughout the central part of the Shan Highland one can find individual ranges rising 2,500 to 3,000 feet above the surrounding land (Figs. 1 and 2). Typically even surface forms occur in the western portion of the Southern Shan States where wide plains interchange with level divides. Most characteristic here are the morphologic contrasts between karstified limestones, metamorphic intrusive rocks and shales. Interlocking systems of karst regions and of faulted basins filled with late Cenozoic freshwater beds, produce a most intricate drainage pattern, as in the case of the Namtu River. Here, as well as in the Shweli and Taping valleys, south and east of Bhamo, fault-lines determine the northeast to southwest strike of the drainage. These relationships have recently been sketched elsewhere.[6] While most of the Shan Highlands lie between the Irrawaddy and Salween Rivers, it would be erroneous to say that the latter borders the highland like a rift valley. Where I saw the Salween Valley at Kunlong it is a normal though deeply entrenched youthful valley which cuts across all fault-lines and rock boundaries.

The Tenasserim Coast Ranges. In the last and southernmost of the mountain units we find a bewildering variety of surface forms. The oblique arrangement of stream channels and embayments is largely responsible for it. The impact of the monsoon rains on this coast have sculptured the limestone and granite into great knob-like hills. At places level surfaces are encountered though none of these appears to be connected with present

[4] Francis K. Ward: *In Farthest Burma*, London, 1921. M. Stuart: Geological Traverses from Assam to Myitkyina through the Hukong Valley, *Records Geol. Survey of India*, Vol. 54 (1923), pp. 398–409.

[5] H. von Wissmann: Die Quartäre Vergletscherung in China. *Zeitschr. Ges. Erdk., Berlin*, 1939, pp. 241–262.

[6] See footnote 1, H. de Terra and H. L. Movius.

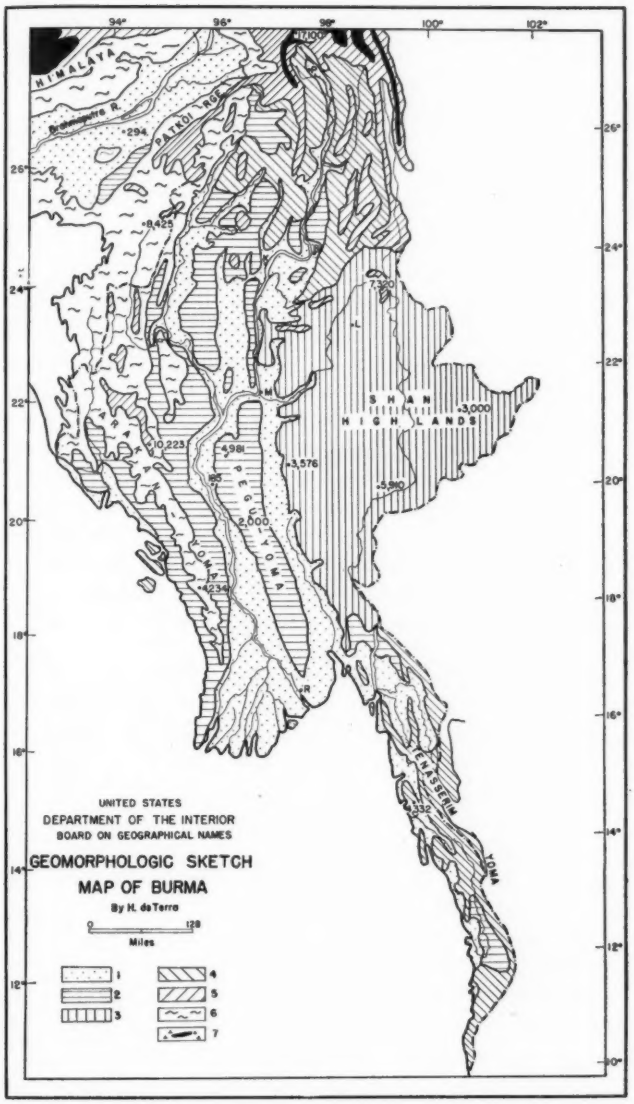

FIG. 2.—Geomorphologic sketch map of Burma. 1, Alluvial plains; 2, Hilly dissected upland; 3, Highlands with subdued relief units and karstified surfaces; 4, Mountainous upland dissected (2,000 to 6,000 feet); 5, Mountainous upland over 6,000 feet; 6, Young fold ranges; 7, Fault escarpment of Shan Highland.

stream action. The coast bears all the characteristics of subsidence, which factor may also account for the widespread accumulation of alluvial silts in the valleys.

The Irrawaddy Basin. The term basin is here used more in its structural sense in as much as it is intended to include not only such relief units as the alluvial tracts of the Irrawaddy and of the lower Chindwin rivers, but of the hilly upland of the Pegu Yoma as well, and of similar low ridges and volcanic forms in Central Burma. Hence there is considerable variety of relief in this basin though on the whole the basin stands out clearly on any map as a major depression (Fig. 1). Its northern limit at Hkamti Long lies at 1,600 ft. above sea-level, and from there to the third defile above Mandalay it slopes about three and a half feet per mile. Here begins a typical basin scenery with the wide meandering stream sweeping across a flood plain from 3 to 10 miles wide, flanked on each side by terraced hills and slopes that surmount the stream level by 1,000 to 1,700 ft. The volcanic cone of Mt. Popa rises out of the plain below Mandalay (Fig. 1). Near Monywa the landscape is dotted with smaller explosion craters, all of which are now extinct. A puzzling feature is presented by level upland surfaces in the Dry Belt region which lie higher than any of the Quaternary terraces. These are either derived from a warped primary and depositional surface or, what is more likely, from pediments surrounding the much dissected central remnants of a Late Pliocene or Old Pleistocene ridge. The terraces of the Irrawaddy have been described in some detail elsewhere (Pl. I, 2). They appear to date back to the middle Pleistocene and to depict a stream cycle with alternating stages of cutting and filling. Analogous features have been observed by myself and other travellers in the Shan Highlands and along the Chindwin, Uyu and Salween valleys.

STRUCTURAL ELEMENTS

The three-fold physiographic division of Burma repeats in a fashion the structural divisions; a geosynclinal basin, an eastern faulted mountain bloc and a western fold belt (Fig. 2). In the latter we may recognize that branch of the Himalayan system which links it with the fold mountains of the East Indies. Accordingly, the Western Mountain belt is made chiefly of tightly compressed folds of marine Mesozoic to early Tertiary strata with the tectonic forces displaying a general movement toward the Indian Peninsula. This western upland presumably existed in pre-Tertiary times as a submarine ridge which rose during the Pliocene above sea-level. From then on it has undergone successive uplifts, especially at the turn of the Pliocene and Pleistocene periods and again during the Middle Pleistocene.

The basin is underlain mainly by freshwater deposits of Upper Pliocene to Quaternary age. Their composition, both lithologic and faunistic, has many characteristics in common with the Upper Siwalik beds of northern India. Where the basin sediments have been buckled up, as in the Pegu Yoma, older marine Tertiary beds appear. The Irrawaddy and Sittang rivers follow at present the less consolidated beds of the lacustrine "Upper Irrawaddyan" and of the Pleistocene, but they cut across the folds as, for instance, at Yenangyaung where petroleum-bearing beds appear in an anticline. One feature, however, distinguishes this structure from that of the Himalayan region: a Quaternary volcanism of the andesitic and basaltic type. Consequently, wide areas in Central Burma were covered by volcanic ashes which give rise to peculiar red-earth deposits. These, as well as the late Quaternary silt and sandy loams of the Irrawaddy tract, have produced soils which form the basis for the fertility of the lowland country.

Contrasting the former two structural units, the eastern upland is of older age as far as the actual folding or orogenic history is concerned. It was uplifted at the close of the Cretaceous and has remained highland ever since. Its geologic composition is incompletely known. There are four major complexes of rock formations. A metamorphic unit with gneisses, marbles and schists which is prominently represented in the west along the great fault-line escarpment toward the Irrawaddy Basin. With it are connected the occurrence of precious stones in the Ruby Mines district, of vast ore deposits (silver and lead) at Bawdwin, and of scattered but highly important outcrops of antimony, tungsten ore, wolframite and tin ores. The latter are found chiefly in the Southern Shan States and in the Tenasserim Coast Range where begins the famous tin belt of Malaya. A second rock unit is represented by thick masses of Paleozoic limestone and dolomite. They form prominent massifs and generally support a poor vegetation, particularly at higher altitude levels. Drainage is poor and of the karst type. Another formational unit is found in the form of red beds of Jurassic and possibly Cretaceous age. Generally they are tightly folded and never found in original basin structures. The red shales produce a deep rich soil of red earth type. A fourth group is represented by freshwater beds containing lignite. They occur in isolated faulted basins near Lashio and farther south. The coals are poor in quality and have no industrial significance. These basin formations are of late Pliocene and Pleistocene age and are presumably connected with the more recent faulting which accompanied the various young uplifts.

A noteworthy feature of this eastern highland is that its more recent uplifts appear to correspond in time with those of the Western Mountain Belt. This tectonic synchronism of the mountain frame suggests that we

are dealing with a "grossfaltung" type of structure with two anticlinoria flanking a subsiding basin. The orographic alignments resulting from this type of structure are very significant for the climatic pattern of the country.

CLIMATIC FACTORS

Of all the meteorologic data available on Burma none are perhaps as complete and as expressive of climatic factors as rainfall (Fig. 3). There are altogether 23 official weather stations and perhaps three times as many semi-official rain-gauge stations with recordings done by overseers of the Forestry and Public Works Departments and by certain private agencies, such as the big timber-trading companies. Official weather observations are now published in Rangoon in the *Burma Monthly Weather Review,* but previous to 1938 they were included in the *India Weather Review,* Poona. Considering the total surface area, the coverage would seem to be far from adequate. It is this imperfection which in large measure would account for certain problematic features on our map, such as the limits of the heaviest rainfall belt in the eastern delta region and the continuation of the corresponding western rain belt into the northern mountain frame. Here the map shows a blank due to complete absence of reliable observations.

Perhaps the most striking characteristic of the rainfall map is the orographic control of the general rainfall zoning. The Southwest Monsoon is caught in the great funnel-shaped Irrawaddy Valley and modified accordingly. Naturally, where the rain-bringing air masses strike the western mountain frame and coast unimpeded the rainfall is heaviest, as along the coast of Arakan and Tenasserim where some stations have recorded annual precipitation exceeding 200 inches. But where the mountain frame causes the monsoon to lose its moisture, as along the eastern flank of the Arakan Range, or where it must travel for 200 miles up the valley, its effectiveness is diminished to such a degree that it becomes necessary for the Burman farmer to irrigate his land artificially over an area of more than one million acres. In addition there is the rain-shadow effect of the low southern portion of the Arakan Yoma on precipitation in the delta. Here again paucity of meteorologic records hampers complete recognition of this extraordinary relationship between low elevation and precipitation. For the same reason it is hardly warranted to depict the areal distribution of climate in terms of Köppen's classification. Yet for some regions this is possible in a very general way. The Arakan Coast (Akyab) has a typical monsoon climate of the *Am* type, and so have the harbor towns of Mergui, Tavoy and Moulmein. The lower delta shows modifications of this same type toward the tropical savanna (*Aw*) climate. In Upper Burma (Bhamo) with an an-

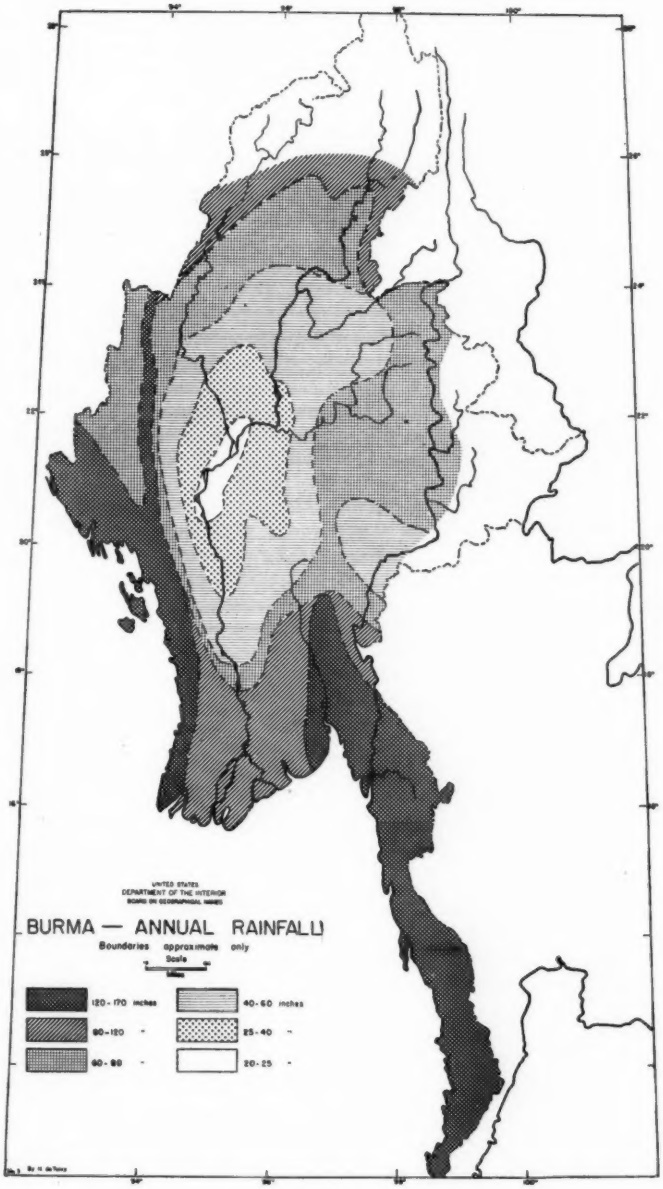
UNITED STATES
DEPARTMENT OF THE INTERIOR
BOARD ON GEOGRAPHIC NAMES
BURMA — ANNUAL RAINFALL
Boundaries approximate only
Scale
120 - 170 inches
90 - 120 "
60 - 90 "
40 - 60 inches
25 - 40 "
20 - 25 "

FIG. 3

nual temperature mean of 61 (1938–39), and in the Northern Shan States (Lashio) there is a humid subtropical climate which approximates the *Cw* class of Köppen. In the Dry Belt, on the other hand, with its high temperatures and low humidity, semi-arid conditions prevail (*Bsh*).

Some general climatic features are of interest.[7] The rainy season begins in the third week of May and generally terminates in the third week of October. The maximum of rain comes in the middle of July. In the rainfall zones between 25 to 80 inches, fluctuations between drier and wetter years are never so serious as to cause distress for the farmers. During the hot season in April and May, dust storms are frequent in the Dry Belt which accounts for the accumulation of wind-blown deposits. Freezing temperatures occur in January from 3,500 feet altitude upward, so that light frost is typical for most of the Shan Highlands. On the higher mountain crests, above 10,000 feet, from about the 26th parallel on, snow is encountered for two or three months of the year. A general picture of the temperature regime may be had from the following statistical data.

Monthly Temperature Means in Burma for the Year 1939

Elevation in feet, degrees Fahrenheit, temp. extremes in parentheses

Station	*Elev.*	*Max. Temp.*	*Min. Temp.*	*Month*
Bhamo	386	76.1(81)	46.9(41)	January
		81.8(89)	54.0(45)	April
		86.1(92)	76.3(74)	July
		86.5(91)	70.2(65)	October
Lashio	2,802	73.8(77)	45.8(40)	January
		78.2(85)	48.9(43)	April
		80.8(87)	70.5(68)	July
		82.7(86)	63.5(61)	October
Maymyo	3,540	72.5(76)	45.8(40)	January
		76.7(83)	45.9(39)	April
		76.4(82)	67.1(65)	July
		79.1(84)	61.8(58)	October
Mandalay	252	81.6(85)	52.6(47)	January
		88.8(95)	57.8(50)	April
		91.6(96)	78.1(76)	July
		90.3(93)	74.0(71)	October
Pyinmana	320	87.1(91)	55.2(50)	January
		92.7(99)	56.6(50)	April
		85.5(90)	75.2(73)	July
		90.9(93)	74.0(71)	October

[7] Very informative chapters on the climate of Burma are found in W. Konau: "Landschaftliche Gliederung von Britisch Burma," Dissertation, Hamburg, 1935, and in K. Stein: Birma; Das Stromgebiet des Irrawaddi, *Mitt. Geogr. Ges München*, Vol. XXIV (1931), pp. 1–101.

Station	*Elev.*	*Max. Temp.*	*Min. Temp.*	*Month*
Rangoon	18	91.1(95)	67.6(63)	January
		97.3(101)	76.9(73)	April
		86.7(90)	76.1(74)	July
		90.0(94)	76.5(73)	October
Akyab	29	82.5(88)	58.3(54)	January
		90.4(92)	76.9(71)	April
		83.3(87)	76.4(75)	July
		87.5(91)	76.7(74)	October
Tavoy	19	90.5(95)	68.1(63)	January
		94.7(99)	75.4(70)	April
		82.7(89)	74.2(71)	July
		89.2(93)	74.0(71)	October

VEGETATION ZONES

If the basin and mountain frame type of relationship determines rainfall distribution, it is equally evident from the *vegetation map* that this is also the case as regards plant life (Fig. 4). There is the same general zoning with tropical rainforest occupying the windward slopes of the frame while the leeward sides are occupied by deciduous and semi-deciduous forest. In this general plan the Dry Belt offers the most striking contrast to the rainforest.

Considering the significance of vegetative life for a characterization of the natural regions, a brief description of the vegetation types is quite essential. Stamp[8] has classified the vegetation of Burma on ecologic grounds and has given to the most outstanding vegetation groups Burmese names (*pyinkado* forest, *than dahat* scrub forest, etc.). Obviously it was not possible to adopt his scheme for this purpose which requires not only a classification embracing all vegetation types but one which may be applied regionally in Southeastern Asia. Also my observations in the Shan Highlands and in the foothills of the Western Mountain Belt convinced me of the necessity to differentiate between a semi-deciduous forest with coniferous or evergreen broadleaf associations and a mixed forest with grassland, such as characterizes the Shan Highlands. In other words, my own classification is climatic rather than ecologic. It appears to agree in broad outlines with that given by H. von Wissmann[9] who included the central and major portion of the Shan Highland in his semi-deciduous forest with oak and pine.

[8] D. L. Stamp: *The Vegetation of Burma from an Ecological Standpoint*, Calcutta, 1925.

[9] H. von Wissman: Die Klima—und Vegetationsgebiete Eurasiens. Zeitschr. Ges. für Erdkunde, 1939, pp. 1–14.

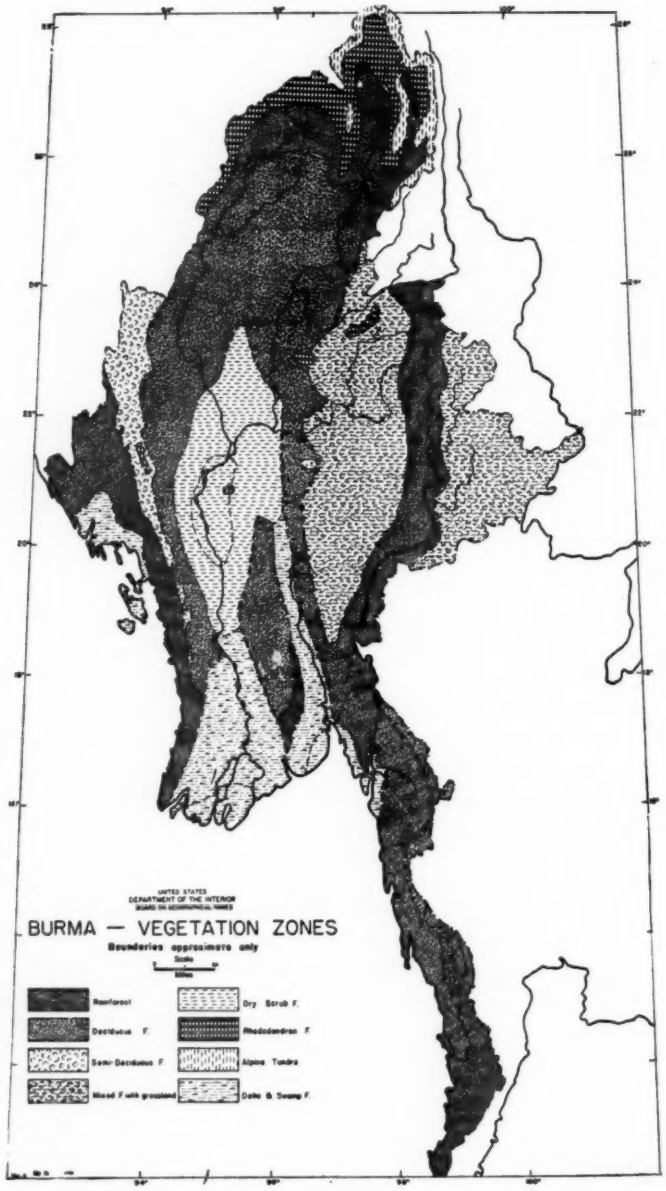
UNITED STATES
DEPARTMENT OF THE INTERIOR
BURMA — VEGETATION ZONES
Boundaries approximate only
Scale
Rainforest
Deciduous F.
Semi-Deciduous F.
Mixed F. with grassland
Dry Scrub F.
Rhododendron F.
Alpine Tundra
Delta & Swamp F.

FIG. 4

Classification of Plant Zones. Generally speaking, the scheme here adopted has the advantage of covering the entire range of vegetation in Burma, and the number of divisions is kept within a limit easily comprehended on climatic grounds. Of eight plant associations (Fig. 4) two belong to the temperate climate (alpine tundra and rhododendron-coniferous forest) and one to a subtropical climate (mixed forest with grassland). All of these lie within the 32° F. isotherm and suffer varying amounts of frost. These are the forests lying above 3,000 ft. altitude, though in the northern regions this relationship is greatly modified by increasing rainfall at higher altitudes. Here both rainforest and deciduous forest thrive as high as 6,000 and 7,000 ft. But generally speaking, it might be said that the 3,000 ft. contour line separates a group of lowland vegetations (subject to wide variations of local climate and soils) from a highland group. A second general characteristic is to be seen in the significance of the 80-inch isohyet for a separation between evergreen rainforests (or delta forests) and the tall deciduous (or mixed) forests. In the area having more than 80 inches of rain a year, precipitation is the dominant factor in determining plant associations, with soil factors playing only a modifying role. In areas with less than 80 inches, both these factors are almost equally balanced. A third discriminating feature is the delineation of the "Dry Scrub Forest" or Dry Belt region by the 40-inch isohyet. Here edaphic factors must be made largely responsible for the checkerboard pattern of thorn scrub and savanna forest. This type of vegetation must be regarded as an extreme modification of the deciduous forest.

The "Delta and Swamp Forest" actually comprises two types of vegetations, the cultivated paddy lands and the variety of tidal water floras for which the monsoon coasts of Asia are famous. The reason I refrained from separating these two on the map is that paddy lands are found outside of the delta, in Central Burma and in the Shan Highlands where a clear delineation would have been neither possible nor advisable considering the emphasis of this particular study on the larger natural regions.

A brief characterization of the eight plant zones will help in the understanding of the vegetation map.

Rainforest. Its most typical development is found in the Tenasserim Coast Ranges for here the dense tall canopy is matched by an ever denser and rather impenetrable underbrush with creeping and climbing plants, mosses, orchids and ferns. In other areas, like the Pegu Yoma, undergrowth is somewhat less dense. Trees reach a height of 250 ft., though generally closer to 180 ft. This tall forest is largely composed of members of the *Dipterocarp* family with other genera like *Ficus, Hopea, Vatica* and *Paynea,* mango and cedar. Palms and bamboo form a lower story and are generally intergrown with thick underbrush.

The more open type of rainforest clothes the slopes of the Pegu Yoma where water-logged soils supplement the relatively low rainfall (80 inches). In the northern rainforest region, sal trees (*Shorea assamica*) are dominant. Here rainforest is replaced at higher altitudes by misty oak forests. A narrow belt of rainforest accompanies the Salween stream to about 25° N. Lat.

The Deciduous Forest. It has much greater variety of plant associations than the rainforest. Two main types of deciduous forest occur: the ironwood (*pyinkado*) and the teak forests (*eng*). Creepers and climbers are still present as in the rainforest and so is bamboo. Leaves are shed in January or February and up to the end of March but begin to grow again before the rains come. Ironwood forest (with the dominant tree *Xylia dolabriformis*) thrives best in regions having 80 to 120 inches of rain a year, though, where soils are very permeable, occurrence in areas having higher rainfall is not rare, as in South Arakan, on the southern slopes of the Pegu Yoma and in the foothills of the southern Arakan Yoma. The teak forest, so called because teak timber is commercially extracted from it, is somewhat thinner. Ironwood and teak (*Tectona grandis*) are prominent. Other trees included in this association are *Bombax, Sterculia, Gardenia, Eugenia,* and *Dellenia,* some of which are evergreens. Sparse bush and grass vegetation are responsible for the more open aspect of this type of forest. The tallest teak trees are invariably encountered on sandy loam soils. A wet and a dry type of teak forest may be distinguished; the latter, with bamboo thickets, is found at the edge of the Dry Belt and in the northern Shan Highlands (Pl. I, 3). The wet teak forest thrives best under 65 to 90 inches of rain, as for instance in North Tenasserim, Pegu Yoma and near Bhamo and Katha in Central Burma.

Semi-Deciduous Forest. In this association we find types such as oak, walnut, *Bombax,* and genera of the tea-tree family mixed on the one hand with broadleaf evergreens like rhododendron, *Gardenia,* laurel and on the other with pine and fir. Conifers occur on higher crests of the Arakan Yoma and Patkoi Ranges. Bamboo and cane are always present and have been observed as high as 13,000 ft. Oak mist-forests with typical tree moss cover the slopes of the northern mountains. The upper limit of the coniferous forest generally is at 8,000 ft., beyond which height rhododendron and laurel dominate.

Mixed Forest with Grassland. This is a modification of the former type but with a definite savanna aspect at places. However, it would not be altogether correct to employ the term savanna because the grassland is generally quite separate from forest. While the former is most extensive in the Shan Highlands on broad valley plains or on ill-drained limestone soil, the

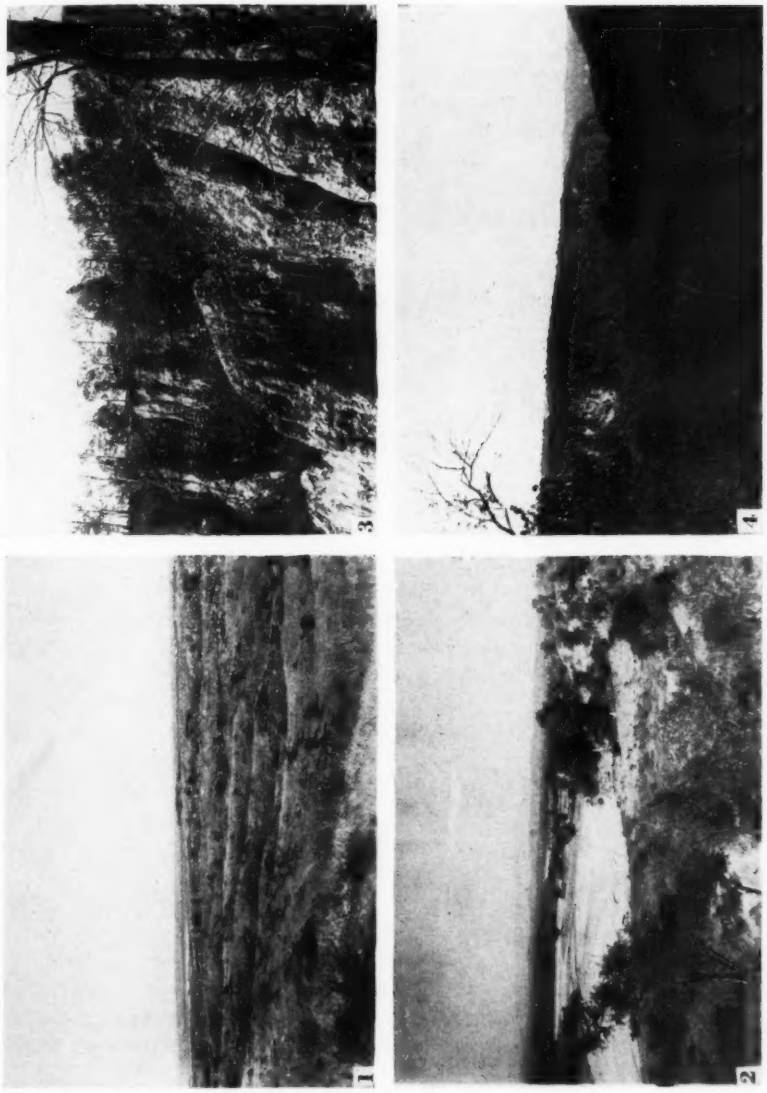

PLATE I

1. Dissected terrace landscape south of Chauk in the Dry Belt with Irrawaddy river in background. Thorny hardwood scrub and grass cover.

2. Edge of ebony forest with savanna in Yaw Valley near Pauk.

3. Deciduous hardwood forest on margin of Dry Belt near Mongmit.

4. Mixed (Semi-deciduous forest) along Namtu Valley at Gogteik gorge in Northern Shan States.

forests are found on slopes and mountain ridges with underbrush. Bamboo and cane occur, but very little grass (Pl. I, 4). Oak, walnut, chestnut, flame-trees, silk cotton trees, and plantains mix with laurel, Magnolia, and rhododendron. The limestone ground, especially above 6,000 ft., generally is quite barren, and where karst topography prevails clusters of willow, cherry, rose and laurel surround the sink-holes. The Khasia pine becomes more numerous in levels above 6,000 ft. Along the deeply incised Salween Valley rainforest accompanies the stream from 500 to 1,000 ft. above its level.

Dry Scrub Forest. This comprises the Dry Belt vegetation in which savanna forest is found in the regions lying peripheral to the 35-inch isohyet. Ebony (*Diospyros*) forest with *Terminalia* and *Pentacme* trees is typically developed in the Yaw Valley west of Pakkoku (Pl. I, 2). On the left bank of the Irrawaddy, south of Mandalay, and on the Pegu Yoma scrub forest dominates, with a short growth of hardwoods (*Tectona hamiltoni, Terminalia oliveri, Acacia catechu*) in association with lemon and star apple trees (*Bascia variabilis*) which display low branching, thereby giving this vegetation a scrub aspect. At the upper edge toward the dry teak forest, I frequently observed, as east of Chauk, stands of Cycads (*Cycas siamensis*). A third and driest sub-zone lies in the centre of the Dry Belt where rainfall is below 25 inches a year (dashed line in Fig. 4). This is the thorny scrub, from 3–5 ft. high, with *Acacia* and *Euphorbia* as the most common forms and a grassy ground (*Andropogum*) vegetation (Pl. I, 1). Near the river Palmyra palms occur in natural or cultivated stands.

Rhododendron Forest. This is a temperate type of forest, restricted to higher altitudes, from 8,000 ft. upward, and most typically developed in the high watershed region of the north. As a forest it is always mixed with fir (*Abies forrestii*) or Formosa pine (*Taiwania*), the latter reaching a height of 225 ft.: Rhododendron trees, maple, cherry, and magnolia are typical, with underbrush of willow, *Spiraea,* snowball, juniper and ferns. The ground is covered by moss and grasses. Bamboo is locally present.

Alpine Tundra. Under this term are included a number of high altitude vegetations such as primrose meadows, mossy heaths with scattered dwarfed juniper and rhododendron shrub or low stands of cherry and magnolia. All three appear in combination, with primrose meadows and rhododendron shrub starting at levels of 10,000 feet. This plant association differs greatly from that of the Tibetan Plateau in its wealth of evergreens and perennials which are less typical of the arid wastes of Tibet.

There is no doubt that the vegetation of Burma reflects more minutely the great number of variants of the country than any other form of organic life. Its human racial composition looks simple in comparison.

RACIAL COMPOSITION

This fourth component element of the natural regions has been sketched in Fig. 5. The threefold physiographic division of the country into a western highland, a central lowland and an eastern highland belt is reflected in the major distinction between Hill Peoples (or Chins), Burmans and Shans. In addition there are remnants of older aboriginal populations.[10]

In the west is the home of the Chins, as the Burmans call the tribes that inhabit the mountains west of the Irrawaddy. Very little is known of them anthropologically. In contrast to the Burmans they are distinguished by great tribal and linguistic diversity. There are no less than 60 different languages and dialects in use amongst these hill peoples as compared to about half that many in the Shan States. One may distinguish between an older mixed group of peoples of which the Thaungtas and Nagas are representative and the more recent migrants like the Kachin, Karen, Khamti (a Thai people), and Shan. Somewhat darker skinned than the Burmans, the Kachins are round faced like the Malays with straight hair and relatively high nasal ridges. Their migration history is one of the most spectacular illustrations of expansion prior to Western colonial occupation. Two hundred years ago they spread from the Upper Chindwin southward and had covered practically the entire western mountains when the last or Third Burmese War broke out (1885). Fighting in the ranks of the Burmese army gave the Kachins their last chance to spread to southern Burma. It is conceivable that they might have overrun the country if the inauguration of the new regime had not worked toward stabilizing of internal political conditions. Of the older, so-called Kuki-Chin group, the retaining of the hoe-culture and of certain ancient dialects (with affinities to the non-Burman Mon-Khmer language) are indicative of greater antiquity of settlement. Hence it would seem that these people represent an ethnic layer derived from a first wave of migrants which subsequently united along the Indian frontier (Nagas) with tribes in Assam.

The second large complex, the Burmans, occupy the Irrawaddy Valley, or the "heartland of Burma," which has given them, through the unifying influence of rice cultivation, a more compact aspect of settlement than any other racial group. Their skin color is somewhat darker as compared with their eastern neighbors, the Chinese and Shans (Thai). Their stal-

[10] Authoritative accounts of the races of Burma may be found in the *Census of India*, 1931, vol. XI, Rangoon, 1933; A. Buschan: *Völkerkunde*, Berlin, 1922, vol. II, p. 738 ff; Sir Frederick Fryer: Tribes on the frontier of Burma, *Proc. Central Asian Soc.*, 1907, pp. 1–28; C. J. Forbes: *British Burma and Its People*, London, 1878; E. von Eickstedt: Das Rassenbild des westlichen und zentralen Hinterindien, *Anthr. Anzeiger*, Vol. V (1928), pp. 259–268.

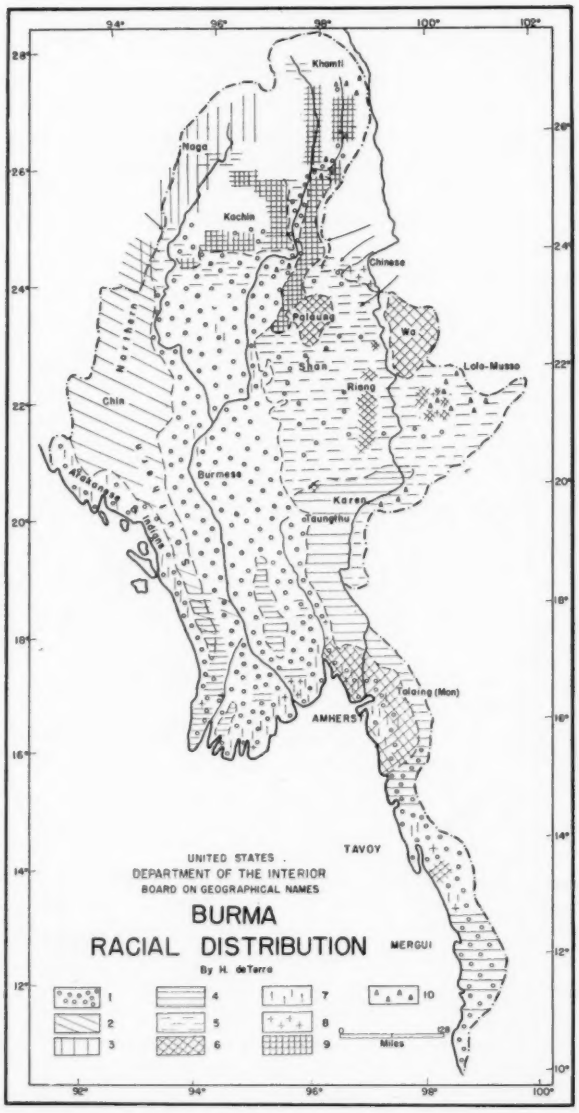

FIG. 5.—Burma racial distribution. 1, Burmese; 2, Chin; 3, Naga; 4, Karen; 5, Shan; 6, Various aboriginal peoples; 7, Indians; 8, Chinese; 9, Kachin; 10, Lolo-Musso.

wart physique and outstanding Mongoloid features characterize them as the most representative outpost of Mongoloid peoples in Southeastern Asia. A vigorous and most attractive people, they have already begun to burmanise the racial minorities.[11] Judging from historic records, they constitute a second wave of migration which started in the eastern portion of the Upper Chindwin around 200 A.D. and which found its political expression in the founding of the kingdom of Pagan around 800 A.D. In constant warfare with the Shans on one side and the Chins on the other, they gradually replaced the aboriginal lowland dwellers, such as the Talaing or Mon, and through intermittent and rather successful raids into Thailand, managed to hold and expand their influence over the entire Irrawaddy tract and coastal regions. In recent years, clashes with Indian emigrants have focussed attention to the fact that Burma is an underpopulated monsoon country facing serious immigration pressure from India.

As a third large racial group on the map appear the Shan (Thai), that adventurous race which has spread further in southeastern Asia than any other. Coming from Yunnan and Szechwan, the Thai people constitute the third and youngest migration movement which was deflected by the Burmese and directed southward along the Mekong and Salween rivers. As allies of Kublai Khan's expedition into Burma (1275 A.D.) they spread in the Irrawaddy Basin but were driven out two hundred years later by Burmese and Chinese forces. Of light tan skin, relatively small stature, and straight black hair, they approach the South Chinese type more closely than do the Burmans. A tendency toward clannishness and a traditional aversion against the Burmans have deprived the Shans of Burma of opportunities for political self-assertion.

All of these three major groups, Chins, Burmans, and Shans have successively, and each in its own way, displaced the aboriginal population, remnants of which are represented by the Palaung, Wa, Riang and Talaing (or Mon). The arrows in the northeastern corner of Fig. 5 indicate the main migration routes from China and the wedging apart of the aboriginal population by Thai and Burmans. Linguistically these earlier peoples are linked by usage of the Australasiatic Mon-Khmer languages while racially they seem to be of various origins. The Wa for instance, primitive head-hunting tribes east of the Salween, carry primitive Mongoloid and Dravidian features (prominent cheek bones, slanted eyes, heavy eye-brow ridges, dark skin, bushy hair) while the Palaung are a primitive moderately Mongoloid group of lighter skin color than the Shans, moderately high nasal ridge and robust body build. The Talaing differ not much from the Burmans but for their shorter stature and stockier build. Very little is known of the Riang,

[11] John L. Christian, *Modern Burma*, Berkeley, 1942, p. 14.

or Yang as the Shans call them, presumably because they are greatly mixed with the Karens. The Karens are akin to the Shans and have, like them, been almost completely driven out of the Irrawaddy lowland.

The entire "ethnological thicket" of Burma is, of course, indicative of a long and varied record of migrations from Southwestern China. It is an interesting fact that as early as the Paleolithic, Burma was more closely linked to the cultures of China than those of India.[12] The history of the Burma-China frontier is one long succession of migrations by various tribes who were displaced from their original homelands about the middle Yangtse by superior socio-political forces aspiring after southward extension and unification of the Chinese empire.[13] This process began shortly prior to the beginning of our era. It is small wonder that these migrant tribes found in their new environment west of the Salween strong inducement for rapid development of their agriculture heritage.

With this brief characterization of the racial distribution in Burma, a point has been reached where the component factors of the natural regions may be brought concertedly into a description of the landscapes, many of which have of late been the scenes of important military actions.

THE NATURAL REGIONS OF BURMA

Arakan Coastal Plain. As a coastwise gateway of active migration from India this region deserves particular attention (Fig. 6). It is the narrow coastal lowland between Sandoway and the border north of Akyab. Typical is the great variety of contrasting vegetations on such a small area, a feature which no doubt has to do with the windward location and the greatly differentiated relief. Mangrove swamps accompany or fill the inlets and estuaries. Dune forest of *Casuarina* trees are encountered in coves and on less indented coast lines. Palms and plantains surmount the bamboo and grass covered plains and low sandrock hills. On the latter also appears deciduous forest with the characteristic ironwood tree (*Xylia dolabriformis*). Around cities and villages are found plantations of coconut, nipa and Palmyra palms, and places like Akyab or Sandoway have made truck gardening profitable. Rainforest covers the hill slopes of the Arakan Yoma and the Chin Hills, and on forest clearings the bamboo (kayin) appears as a firm soil-retaining overgrowth. Rainfall is generally over 200 inches a year, and at places it is 250 inches. Sea breezes offset somewhat the unfavorable effect of torrid dampness so that the climate may be considered more favorable than that of the delta land in Lower Burma. Hence native enterprise flourishes in

[12] See H. de Terra and H. L. Movius, *op. cit.*

[13] A very instructive summary of these movements is found in the introduction to A. R. Colquhoun's book, *Amongst the Shans,* New York, 1885.

many different directions. Rice is extensively grown from the coast up to the higher valleys. It is sown at the beginning of the rainy season in June and harvested in November. Fishing, lumbering and intercostal trade are the important non-agricultural pursuits. For many centuries, and certainly back to the time of King Asoka's reign in India (264–228 B.C.) Burma's intercourse with India was through this coastal province. Hence there is racial mixture between emigrants from Assam, Bengal and Madras on one hand, and the old Arakanese population (of Burman stock) and modern

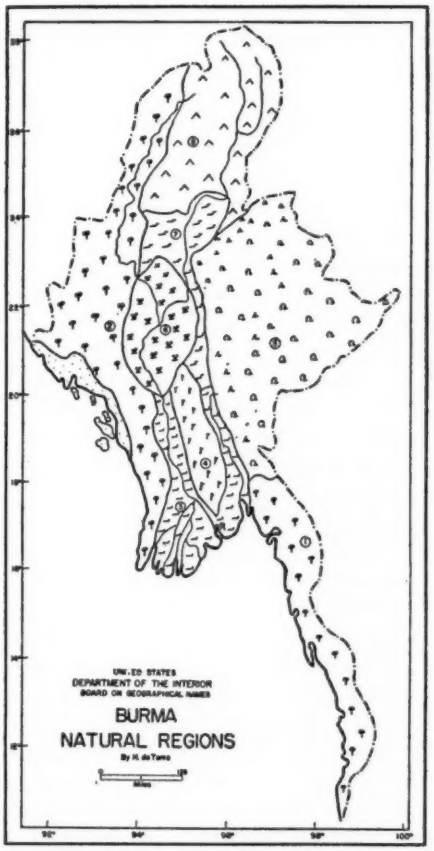

FIG. 6.—Burma natural regions. 1, Tenasserim Forest Belt; 2, Western Forest Belt; 3, Lower Valley; 4, Pegu Yoma; 5, Shan Highlands; 6, Dry Belt; 7, Upper Basin; 8, Meridianal Valley and Range Province.

Burmans on the other. No doubt, with the increasing measure of public health service under British supervision this region will be capable of supporting a larger population than at present.

Western Forest Belt. Two separate divisions of this belt may be distinguished: the rainforest on the seaward side and a deciduous forest on the leeward slope. The difference in annual rainfall between the regions amounts to about 100 inches. A third type of vegetation of the semi-deciduous type thrives at higher levels, with coniferous forest becoming prominent between 4,500 and 6,000 ft. The rainforest on the seaward slope is practically impenetrable except along streams and is one of the most thinly populated regions of Burma. Large tracts are completely uninhabited. Scattered clans of Kuki-Chin, Khamti, Taungtas and Nagas penetrated this dense forest from the eastern slopes and make a precarious living by hunting, fruit-gathering and hill-cultivation of burnt-over forest. The deciduous forest on the eastern slope, with its valleys leading into open foothills, supports Shan and Burman farmers most of whom came from the plains, introducing the cultivation of rice, sorghum, barley, maize and tobacco. In the less accessible Chin Hills rice is often planted on stream terraces or on artificially terraced hill slopes while sorghum and maize are cultivated with the hoe on freshly burnt forest. In the deciduous and mixed forest, settlements usually lie on higher slopes or hill crests, while the valleys leading toward the drier piedmont harbor the more substantial villages of Burmans, Karens and Shans. In the piedmont zones are found bamboo thickets (kayin) and elephant grass which cover the deforested areas.

Rugged topography and dense tropical vegetation make the Western Forest Belt into one of the least desirable habitats of Burma. The few mule paths that lead across the Arakan Yoma and the Patkoi Range in the north indicate the disinterestedness on the part of the hill tribes in any type of commerce. Such an attitude has discouraged many an enterprising native and foreign trader. At present efforts are being made to construct a road leading from Ledo in Upper Assam across the northern slopes of the Patkoi Range to northernmost Burma.

Meridianal Range-and-Valley Province. This area comprises the northern mountain frame of Upper Burma which includes the watershed ranges between the Irrawaddy, Brahmaputra and Salween drainages southward to the latitude of Katha. Rugged topography is characteristic there and an altitudinal zoning of plant associations ranging from deciduous and rainforest to alpine tundra. The former is characterized by wet teak forest containing valuable timber reserves which are exploited along the Irrawaddy drainage in the Bhamo and Katha districts. Except for such valleys as the Mali Hka and Nmai Hka, the Upper Hukawng and Uyu rivers, there are

hardly any settled areas north and northwest of Myitkyina. The relief is more formidable there than in any other region of Burma, and the combination of steep-angle slopes with dense forest cover forbids any large-scale human intercourse. The highest peaks exceed 19,000 ft. altitude. The main caravan road leads from Myitkyina to Putao in the Hkamti Long area. Mist-shrouded oak and rhododendron forests thrive up to 12,000 ft. where they cover the depositional remnants of former glaciations. Alpine meadows and heaths were observed near the high passes leading to Assam and the Sikang province respectively. Despite the close proximity to Tibet and Assam no active migration appears to take place from either country. And yet in former times there must have occurred population shifts as indicated by the variety of peoples that inhabit these lonely regions. The population varies racially, with Thai (Hkamti), Kachins and Burmans found in separate valleys. Barley, sorghum, and maize and a little rice are planted in the valley plain of Putao practically at the foot of the Tibetan Plateau. There is some pasturing by Tibetan nomads on the Burman side of the high passes leading to Eastern Tibet.

The Upper Basin. This is the northern portion of the Irrawaddy lowland from the basin of Myitkyina on the north and across the alluvial tracts and lowlands of Bhamo and Katha, including a narrow belt of piedmont along the Shan Highland, to the low Irrawaddy-Sittang divide. It is the basin-and-hill type of relief with savanna forest, grass and cultivated lands in the plains, and deciduous forest in the hills. Dry teak forest occurs in low altitudes, but large areas already had been deforested when the British took over the administration. Above 3,000 ft. evergreen trees and shrubs appear in large numbers forming a mixed forest with transitions to the rain-forest type. For the first time rice cultivation on a large scale appears and is especially noteworthy in the eastern piedmont zone along the Shan Highland, with irrigation provided by canals which branch off from the hill streams. Tobacco, millet, cotton, and sorghum also are grown. Lumbering and fishing are important, and Bhamo has for centuries enjoyed overland trade with Yunnan. Shans, Kachins and Burmans share in the racial composition, though Shan (or Thai) is the lingua franca in the district of Bhamo. The Chinese element is notable in this town and its vicinity, the frontier with Yunnan being only twenty miles away from there. The Taping Valley makes an ideal outlet for the caravan road coming from Tali, P'ao-shan and T'eng-ch'ung. Steamer traffic on the 1,000 mile stretch from the sea to Bhamo can be carried on unhampered throughout the year and keeps up a constant flow of traffic. This intersection of waterway and overland traffic assures Bhamo a unique place in the commerce of Burma's remote northern provinces. In this respect it is second only to Mandalay

where river, rail and road transportation converge from all quarters. Depending on the future development of the Burma Road, Mandalay will in all likelihood remain the chief place of transshipment for transit goods to Burma's northeastern borderlands.

The Dry Belt. This is the most striking of all the natural regions of Burma. Its boundaries are delineated by the 40-inch isohyet. The xerophytic vegetation dominates, with dry teak (or *eng*) forest in the marginal zone and an island of deciduous forest on the elevated cone of Mt. Popa, surmounting a barren landscape covered by thorn scrub and grassland. Open tree savanna with *Acacia,* cycads, *Euphorbia,* and *Terminalia* trees on a much-dissected relief are subject to sheet-wash erosion and seasonal windstorms. Settlements lie along stream valleys, especially along the Irrawaddy and its major tributaries and many are marked by stands of Palmyra palms. The oil fields of Yenangyaung, Chauk and Yenangyat lie in the driest and most central part and have caused a mushroomlike growth of settlements bearing a certain likeness to American "boomtowns." The Irrawaddy flows in a wide floodplain, up to five miles wide, and here rice is grown extensively. On the low terrace flats red silt soils permit the growth of sorghum, sesamum, groundnut, cotton and tobacco. The main crop, sesamum, grows best in areas having the most regular and not too torrential rainfalls. Ever increasing use is made of artificial irrigation both through construction of small reservoirs in hilly sections, and by tapping of streams descending from the eastern and central uplands. One and a half million acres are already under irrigation, so that the Dry Belt has become the one agricultural district able to absorb large numbers of Burman migrants coming from the crowded delta sections. The rural population is overwhelmingly Burman while in the towns Indians have taken over a good deal of the trading. A lively river trade is carried on, and fishing is the most important non-agricultural pursuit.

Shan Highlands. The elevated mountain region east of the Irrawaddy and Sittang lowlands has the great climatic advantage of cooler seasons and about twice the rainfall of the Dry Belt. Subtropical mixed forest with oak, chestnut, *Bombax,* walnut, magnolia, laurel and pine, and a grassy ground vegetation make for a much more open type of forest as compared with that of the western highland. The western rim is covered by deciduous forest with cane and bamboo thickets. The only section with rainforest is a narrow zone along the Salween. In the valleys, some of which are up to ten miles wide, as well as along lower slopes, rice is a staple crop, and sorghum, sesamum and sugar cane are next in importance. In the mountainous areas tea is planted extensively by the natives (Palaung), and sericulture is carried on traditionally by the Riang or Yang people. Ground-

nut, buckwheat, poppy, and indigo are hill-slope crops, whereas tobacco and cotton are raised in the more protected basin countries. Near Hsenwi I was shown the first tung tree plantations, still in an experimental stage, and near Kalaw and Toungoo in the Southern Shan states tangerines, oranges, pineapples and other fruits are grown commercially for the larger city markets of Lower Burma. The population is dominantly Shan and Karen, the latter becoming more prevalent in the south. Of the non-Thai people, the Palaung and Wa are the most prominent (176,000) groups, whereas the Riang, according to Scott,[14] number less than ten thousand.

The last decade has seen great road building activities due no doubt to the final border settlements with Yunnan and Thailand. Each of the railroad terminals, Lashio and Kalaw, serves as a starting point for a road-net branching out toward the eastern borders. The former town is the starting point proper of the famous Burma Road which leads over 750 miles of rugged mountain scenery to Yunnan's capital, K'un-ming. Whether this road will eventually fulfill the expectations of a main traffic artery opening up the westernmost hinterland of China, or whether it will play the lesser role of linking a few border states, nobody can at present foretell. In any case, the Shan States are bound to become Burma's most promising economic reservoir, capable of receiving a great many settlers, including white people. Great mining enterprises, such as the silver-lead mines of Bawdwin, west of Lashio, and scattered mining for wolframite, and tin are promising beginnings.

Pegu Yoma. The upland between the Sittang and Irrawaddy valleys reaches elevations of 2,000 ft., and while the relief is on the whole subdued, steep slopes are locally encountered. Its dense deciduous forests are rich in teak and ironwood, lac and mahogany timber. Relative nearness to the harbor of Rangoon makes these forest reserves especially valuable. Rainforest covers a narrow strip on the southeastern side where sandy clay soils retain much moisture all the year around. Torrid temperatures and high humidity make this a less favorable habitat than either the Shan Highlands or the Dry Belt. The population is dominantly Karen, a branch of the Tibeto-Burman group, and on the southern slope are found the last remaining settlements of the Mon people who at one time had control over most of the region. The area is poor in communications and hence isolated from the busy life of the neighboring lowlands.

Lower Valley. The delta and alluvial tracts of the lower Irrawaddy and Sittang valleys form a fertile triangle of about 10,000 square miles, with its base turned toward the Gulf of Martaban. Except for some ancient

[14] Sir George Scott: *Burma and Beyond,* London, 1932.

beaches and sandrock hills, and for the southernmost tip of the laterite-covered Pegu Yoma at Rangoon, there is very low relief. Most of the lower valley is seasonally inundated by rain- and floodwaters, which makes for ideal paddy land. A homogeneous tough clay with moderate lime content is the preferred rice soil. Vegetation varies with the relationship to tidal water levels. *Heriteria* forest covers the ground elevated above the mangrove swamps. Scrub forest of the deciduous type and elephant grass cover much of the less accessible portions. Rainforest and wet teak forest are encountered on the low ridges especially in the southwestern district of Myaungmya. The muddy fringe of the mouths of the Irrawaddy generally shows a dense scrub which passes into mangrove swamps. Cultivation is intensive, with as much as 98 per cent of the cultivable land given to paddy fields. From this region comes the large export crop of rice. Tidal channels and braided delta streams provide inlets for oversea trade and coastal shipping with their opportunities for employment and prosperity. Rangoon's spectacular rise from a small fever-infested port to a world centre of commerce illustrates the rapid progress of the land in terms of higher standards of living. It is here that the greatest clashes occur between Burman and Indian elements. Indians make up more than half the population of the Rangoon district. Chinese are second to Indians as an alien group but are much less obstreperous and more cooperative. Rangoon with its lumber, rice, and cotton mills, oil refineries, repair yards and wharves, and with the magnificent residential districts, was close to attaining first rank amongst the great ports of the Middle East.

East of the town and around the mouth of the Sittang River the Talaing or Mon people dominate, yet the Sittang is unsuited for navigation on account of a high tidal bore; hence the dearth of commercial establishments in this region. In the western part of the delta, Burmans have mixed with Karens and Indians, and, in towns like Bassein and Henzada, the Indian element is again strongly represented. Less favored by navigability in competition with Rangoon, the harbor town of Bassein nevertheless has a lively river and sea-going trade.

Tenasserim Forest Belt. Though quite uniform in climate and vegetation, this region offers a great variety of landforms. A northern plains-and-ridge division may be distinguished from a southern, much-indented mountainous coast which extends to the Isthmus of Kra. The stream valleys of the Bilin, Salween, Gyaung and Zami rivers converge on the northern coastal plain. All of them descend from the Dawna Range which forms the rugged watershed between the Gulfs of Martaban and Thailand. Their flood plains make ideal paddy land so that, in Amherst district, nine-tenths of the cutivated land is given to rice cultivation. From 500 ft. upward the

terrain is covered by typical rainforest, changing into deciduous forest with lesser rainfall, as in the lower foothills and on the leeward slope of the Dawna Range. Coastal dune and mangrove associations characterize the shore line and islands. The teak forests appear here on the leeward side of the watershed range where rainfall is reduced to about 85 inches a year. Timber and mining products, such as antimony and tin, are exported from Moulmein harbor.

The Salween and Tenasserim rivers have guided migrant peoples southward to the coastal plains. From the north and northeast came the Karens and Shans who contested with the Burman population for possession of cultivable land. In the north is found a substratum of Talaing people, while Indian and Chinese traders are prominently represented in coastal towns. By contrast, the southern mountainous coast is less densely populated, for here there are no modern roads and rail connections. Rainforest over dissected relief is the chief obstacle to the development of this country. As long as the Isthmus of Kra remains an undeveloped possibility for a canal to the Gulf of Thailand, the southernmost tip of Burma will remain a refuge of ethnological curiosities and of tropical wild life.

SUMMARY AND CONCLUSIONS

Of all the component factors the physiographic appears to be the dominant inasmuch as the orographic division into Western Mountain Belt, Irrawaddy Basin and Eastern Highland determines the extent to which the other factors contribute to the character of the natural regions. As far as one can judge from rainfall distribution, the monsoon climate undergoes great modification through the funnelling effect of the basin upon precipitation. Two hundred miles from the mouth of the Irrawaddy delta rainfall is greatly diminished due both to progressive loss over the valley and to the rainshadow effect of the western mountain belt. The deciduous monsoon forest is thereby reduced to a savanna and thorn scrub vegetation. Hence the latter is not an artificial but a natural feature and unlike the delta scrub forest and grassy swamp lands which obviously are of second growth. Northward, the Dry Belt is replaced by rainforest of a subtropical variety occasioned by the general rise of the land, and deciduous forest extends to the edge of the Tibetan Highland where alpine tundra and coniferous forests begin. East of the Irrawaddy Valley precipitation would be as deficient as in the Dry Belt were it not for the concerted effect of higher relief and of deep valleys upon the general track of the southwest monsoon. For, while altitude makes up for the normal loss of moisture in the interior, the Salween valley and the eastern tributaries of the Irrawaddy act as air passages admitting a greater amount of rain than is found on the surrounding uplands.

In the case of racial distribution, orographic control is apparent in the differentiation of three main complexes of which the most compact is represented by the Burman group occupying the Irrawaddy Basin. This is flanked on either side by an incongruous though highly significant mixture of races who inhabit the forested uplands. It is certainly remarkable how the valley with its attendant influences of soil and climate has enforced unity in competition with mutually contesting waves of migrations coming from beyond the northeastern borders. Its three natural regions, Lower Valley, Upper Basin and Dry Belt, form the "ecumene"[15] of Burma in which the master stream surpasses in natural benevolence all other resources. The navigability, the seasonal floods, the alluvial soils and the outlet to the sea form what one might call the "ecumenic potential."

From whatever angle one may look at Burma's political fate in the reshaping of Asia's nationalities, it is already becoming obvious that it is inextricably tied up with the relationship between its own economic potential and those of its most powerful neighbors, India and China. For while the Burma Road signifies reassertion of an age-old tie with the ecumene of the Yangtze Valley, the new Ledo Road from Assam indicates a novel link with the Brahmaputra-Ganges region. Thus the final break with Burma's geographic isolation is at hand, and it has been enforced, as in the case of other Asiatic nations, by western technology with its tendency to overcome natural barriers.

[15] As defined by D. Wittlesey in *The Earth and the State*, New York, 1939, p. 2.

United States Malting Barley Production

JOHN C. WEAVER*

From a long history of cultivation in a wide range of environments and agricultural economies throughout the world, the dominant functional position of barley has become that of a feed grain. In some areas, however, notably in Asia and north Africa, large quantities of barley are still grown primarily for human consumption, in the form of porridge or flatbread. Only since the turn of the twentieth century has barley lost its former importance as a food grain in Russia, and in India it still maintains a significant position among the food-producing crops.[1] Elsewhere in the world this grain plays its part in human nutrition, admittedly minor in relation to the total volume of barley produced, through its ability to serve the non-beverage functions of malt, for pearling, and other specialized uses.

Apart from its use as a feed grain, the most widespread, and from the economic standpoint the most important, use of barley is its use for the production of malt beverages, especially beer. It is estimated that somewhat more than 10 per cent of the total world barley crop, in a currently average year, serves this demand. To be sure, much larger proportions of the barley crop are so used in certain countries, e.g., United Kingdom, Germany, Austria, and the United States, than is the case in the world as a whole.[2]

Many other grains, and practically any variety of barley may be used as livestock feed, but barley is the only grain having the properties required in the making of the types of beer preferred in the United States and Europe. Furthermore only certain carefully handled varieties of barley are acceptable for this purpose. In the economic sense feed barley and malting barley are two distinct grains, since "barley used in beer production is a rather delicate product, much more carefully selected than grain used for any other purpose, even for the production of the finest wheat flours."[3]

Inasmuch as the production of good malting barley involves greater sea-

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* Dr. Weaver, now an Ensign in the United States Naval Reserve, was until recently on the staff of the American Geographical Society and also associated with the Office of the Geographer, U. S. Department of State. He has published two previous papers dealing with geographical aspects of barley production in the United States.

[1] N. Jasny: *Competition Among Grains,* Stanford U. Food Research Institute, Palo Alto, Calif., 1940, pp. 24 and 518.

[2] Jasny, *op. cit.,* p. 518.

[3] *Ibid.,* pp. 52–3.

sonal uncertainties and more care on the part of the farmer than the growing of feed barley, premiums are paid for barley of malting quality. This means that the full effect which the use of barley for malt has on the total extent of barley cultivation is not fully shown by a statement of the amount of barley actually used in the making of malt. Large acreages of barley, which never reach the malting market because of some quality defect and which are subsequently used for feed or some other less exacting purpose, are produced in response to the stimulus of malting barley premiums.

While the economic importance of malting barley is great, the proportion of the total world or United States acreage devoted to its growth is, when compared to that of feed barley, relatively small. Also, the regional limitations affecting the patterns of malting-quality barley production are far more restrictive than those imposed upon the cultivation of barley in general. Recognizing the fact that only under certain well-defined conditions is it wise for the American farmer to attempt the cultivation of barley for the malting market, Harlan warns that "in general, feed barleys should be grown by farmers who expect to use the crop primarily as feed; by farmers in sections where little barley is grown; by farmers in sections where the malting varieties yield decidedly less than feed varieties; and by farmers in any section where farms are of such character that good malting quality is rarely produced."[4]

The cultivation of barley in the United States was originally, and for many subsequent decades, stimulated by the demand for malting barley.[5] It was not until the nineteenth century, and especially the closing decades of that century, that the increasing appreciation of barley as a feed grain began to turn the American barley crop into new channels of utilization.[6] By 1914, it was estimated that only about 38 per cent of the American barley

[4] H. V. Harlan: *Growing Barley for Malt and Feed,* Farmers' Bull. 1732, U.S.D.A., Washington, 1934, pp. 1–2.

[5] The early importance of the influence which the use of barley for malt must undoubtedly have had upon the introduction and establishment of this grain in the United States, is suggested by Persons: "The historical record indicates that the shortage of the beer supply on the *Mayflower* was partly responsible for the landing of the Pilgrims at Plymouth. An explanation from the original manuscript published in 1622, *A Relation, or Journal, of the Beginning and Proceedings of the English Plantation Settled at Plymouth, in New England,* states: 'For we could not now take time for further search or consideration: our victuals being much spent, especially our beer . . .'." Warren M. Persons: *Beer and Brewing in America: An Economic Study,* Revised by Standard and Poor's Corporation, The United Brewers Industrial Foundation, N. Y., 1941, p. 5.

[6] The nature of this development is treated in somewhat greater detail in: John C. Weaver, "Barley in the United States: A Historical Sketch," *Geogr. Rev.,* Vol. 33 (1943), No. 1, pp. 56–73.

crop was used for malting.[7] With the advent of Prohibition the malting use of barley slumped to a position of relative insignificance, only 9 per cent of the national crop being devoted to that purpose in 1929.[8] The steadily advancing importance of barley as a feed grain is shown by the fact that, despite the rapidly dwindling market for malting barley, the largest national barley acreage in the history of the country was sown in that year.

With the repeal of Prohibition and the restoration of a strong malting-barley market, American growers were suddenly faced with the problem of producing a type of quality grain for which there had, for nearly two decades, been little demand. Subsequent years brought widespread changes in the malting barley districts, and the cultivation of this grain has now begun to assume a new and apparently sound position in the agricultural economy of the nation. Of the 271,822,000 bushels of barley produced in the United States in the generally normal pre-war year of 1939, 21.1 per cent was used to provide malt for the making of alcoholic beverages; 1.3 per cent provided malt for other purposes; 9.5 per cent was saved for seed; and 68.1 per cent was used for livestock feed and a few additional uses of minor importance. The 22.4 per cent of the national crop devoted to the making of malt for all purposes was slightly below the five-year average of 27.5 per cent for the period 1934–1939.[9]

Although some of the other grains, notably oats and wheat, have been used in the making of malt,[10] the qualities peculiar to barley have gained for this grain a place of uncontested pre-eminence in consumer preference with regard to its capacity to provide malt for the brewing of beer and allied beverages, and for the malt extracts utilized in a wide vairety of ways. The particular superiority of the barley grain results largely from the fact that "it has protecting hulls, valuable in the malting and brewing process, and contains starch, proteins and enzymes in amounts found desirable for malting."[11] Thus, in contrast with such inter-grain competitions as those exist-

[7] Despite the fact that considerably less than half of the total national barley production was being used for malt in 1914, that year witnessed the pre-Prohibition peak of the brewing industry. There were then in the United States 1392 separate brewing concerns, employing 75,404 men in the breweries alone, and having a total capitalization of $792,914,000. Persons, *op. cit.*, p. 8.

[8] James G. Dickson: *The Status of Barley Improvement from a Technical and Scientific Standpoint.* Reprinted from the Proceedings of the 33rd Nat'l Convention of the Master Brewer's Ass'n of America (Philadelphia, Pa.: Oct., 1936), p. 5.

[9] *Seed Statistics,* U.S.D.A., Bur. of Agric. Econ., [prepared by Hay, Feed, and Seed Division], Washington, D. C., March, 1941, pp. 6–7.

[10] Thomas F. Hunt: *The Cereals in America,* New York, 1919, p. 337.

[11] B. D. Leith and others: *Quality Barley—How to Grow—How to Handle,* Circ. 278, U. of Wis. Ext. Service, Madison, March, 1936, p. 4.

ing among the feed grains, the stimulus to farm production given by the demands of the market for malt has become definitely centered upon a single grain. The farmer's selection of his crop is in this case not determined after a consideration of the relative merits of several grains, but rather through a recognition of the distinctive suitabilities of particular varieties of the one grain, barley.

THE USES OF BARLEY MALT

The barley malt produced in the United States is used largely in the making of alcoholic beverages. The figures issued by the Bureau of Agricultural Economics for the year 1939 clearly emphasize this fact.[12] Of the 60,876,000 bushels of barley used for malt in that year, 94.3 per cent was used in the production of alcoholic beverages, nearly all of it for the brewing of beer.

Since, as already has been pointed out, barley of acceptable malting quality commands premium prices, the brewing industry obviously provides a strong economic stimulus to barley growing in this country. Computed on the basis of average prices over the four-year period 1937–1940, it is estimated that American brewers paid a total of approximately $282,000,000 for malt. The greater part of this enormous expenditure was received by the farmers raising the desired varieties of malting barley.[13]

THE MALTING PROCESS

The primary objective in malting is the conversion of the starch of the barley grains to sugar. This is accomplished through setting in motion certain enzymatic actions and other alterations within the kernel which occur in association with the natural processes of seed germination. Since the rigid quality requirements for malting barley have an important effect not only upon the methods of cultivation in regions where barley is being grown for the malting market, but also upon the ecologic definition of regions in which such barley can be grown, and since these specific quality requirements derive from the nature of the malting process, one must, if only briefly, examine the character of the methods used in the production of malt.

[12] *Seed Statistics, op. cit.*, pp. 6–7.

[13] A bushel of barley, having a standard weight of 48 pounds, is capable of producing approximately one bushel of malt (34 pounds). The average production of one barrel of beer requires about 36 pounds, or slightly more than a bushel of malt. Thus the 54,891,737 barrels of beer produced in the United States during the fiscal year of 1940 represented some 57,600,000 bushels of malt, or about 58,000,000 bushels of barley. Since in the same year, malt and barley exports exceeded imports by 1,726,000 bushels, it is estimated that in 1940, 59,326,000 bushels of American barley were used by breweries at home and abroad. Persons, *op. cit.*, pp. 33–34.

As the first important step after the grain is cleaned, the maltster steeps the barley in cold water until each kernel has become completely saturated. The purpose of this is "to reduce loss from root growth, facilitate uniform modification of the endosperm and aid in the distribution of the enzymes through the starchy mass."[14] The length of time required for this steeping may vary considerably, depending upon the character of the barley variety used, the nature of the season and locality in which the grain was grown, and the temperature of the water in which the steeping is done.

When the steeping process has been completed the grain is spread out and allowed to germinate on the malting floors, where it is carefully stirred in the presence of properly controlled conditions of aeration, temperature, and moisture. As the germinating grain is stirred there is danger of the projecting sprouts being damaged or broken, thus either slowing down or completely arresting growth. Being a protection against this, the firm hulls of the barley grain are very important to the maltster, and it may easily be appreciated why peeled or hulled kernels are regarded as objectionable.[15]

"During the germination process a substance in the barley known as the enzyme diastase is liberated by the barley germ and is distributed through the starch of the barley kernel. The function of the diastase is to convert the starch of the barley into sugar, which can be used by the germinating seedlings. Their germination is stopped by drying when the barley sprout is from three-fourths the length to the length of the kernel. At this time only a small portion of the starch has been converted into sugar, but the diastase has been so thoroughly distributed throughout the kernel that it will begin to function again when the proper conditions are available."[16]

During the last days on the malting floors the grain is dried somewhat, and at the point when the germination has proceeded to the desired degree, the drying is completed in kilns, thus preventing any further enzyme action and consequent sugar loss. After the drying, the shriveled sprouts are removed from the grain and sold as feed for livestock. The dried kernels that remain represent the finished malt of commerce.

GRAIN QUALITY REQUIREMENTS OF THE MALTING TRADE

Because of the precise and exacting nature of the malting process, the barley used in the making of malt must conform to a scale of very definite grain quality characteristics, and malting barley is regarded as a high-priced and delicate commodity. Not until recent years, however, have the various

[14] Leith and others, *op. cit.*, pp. 4–5.

[15] *Ibid.*, p. 520.

[16] D. D. Hill and others: *Barley Production in Oregon*, Oregon State College, Agric. Exp. Sta., Bull. 355, Corvallis, Ore., 1938, pp. 26–27.

implications of the term malting quality been carefully analyzed and accurately defined on the grain market. Prior to the year 1934, large quantities of barley reached the market under commercial grade designations, which, for one reason or another, proved entirely unacceptable for malting use. The grain was purchased almost exclusively by sample according to the differing fancies of the individual buyers, and the establishment of reliable malting barley grades and appropriate and consistent price quotations was impossible. In the presence of this confusion, "at country points the barley crop usually was just 'barley' so far as the producer was concerned, and in the absence of definite grades for malting barley, country buyers found it difficult to correlate country prices for barley of malting type with terminal market prices for barley of this type."[17]

With the repeal of Prohibition and the sudden enormous expansion of the demand for malting barley, a clarification of this situation became imperative. Only certain varieties of barley, cultivated with unusual care, and grown in the presence of particularly favorable ecologic conditions, were capable of producing a grain acceptable to the maltster, and if the grower was to be expected to produce a grain of the desired character, standards stating these qualities had to be established. Furthermore, if the farmer was to expend the additional time and labor required to produce a grain of particular quality, it was clear that specific grades of quality had to be accurately defined and appropriate premium prices quoted.

Accordingly the Bureau of Agricultural Economics of the United States Department of Agriculture made an exhaustive survey of all of those physical characteristics of the barley grain that might serve as a reliable basis for the designation of barley of malting quality and the delineation of grades of varying superiority within that general classification. As a result, a series of standards relating to malting barley grown east of the Rocky Mountains was prepared and made effective on July 2, 1934.[18]

Under the present system, all white barley grown east of the Rocky Mountains, which, upon reaching the market, is found to satisfy the special requirements for malting barley, is, according to highly precise standards, placed in grade classifications numbered 1, 2, and 3.[19] These grade desig-

[17] U.S.D.A., *Yearbook, 1935,* Washington, 1936, p. 226.

[18] U.S.D.A., *Yearbook, 1935, loc. cit.*

[19] To be sure, despite the rigidly prescribed nature of the quality requirements at the terminal markets, there are important year to year alterations in the definition of what constitutes suitable malting quality. For example, in certain years "when the barley crop happens to be of poor quality, beer is made of barley that in other years would be refused indignantly. But in such years the selection of slightly more adequate samples proceeds with special care, and the price spreads become particularly wide." Jasny, *op. cit.*, p. 106.

nations largely determine the price which a particular lot of barley is able to command at the principal markets.[20] In the event that barley reaching the market fails to meet the quality requirements defining the malting grades, it falls automatically into a "feed-barley" classification. Occasionally borderline lots of grain can, through the careful blending and cleaning operations of elevator men, be brought up to the status of a malting grade,[21] but grain of doubtful quality is usually more profitably utilized as feed on the farm where it was grown than as a potential market crop.

The numerous quality factors which determine whether or not barley is acceptable for malting, and its grade designation if it is so classified under the present grain standards, are controlled in large measure by the care which the farmer takes in growing, harvesting, threshing, and storing his crop. In areas ecologically suited to the growing of high quality barley, farmers hoping to sell their crop on the malting market are growing more than just ordinary barley. They must, therefore, have an understanding of the exact nature of the grain required and are compelled to grow and handle their barley accordingly.

Unfortunately the occurrence of especially favorable seasons in areas not normally considered to be suitable for the cultivation of high quality barley, may in certain years cause a flooding of the malting barley market. In such years malting barley prices drop to levels not much above the feed grades, and as a result the farmer who has taken particular care in raising his crop receives little or no compensation for his extra labor. Such growers are likely to take less pains in handling their barley in subsequent seasons and a generally lowered grain quality results.[22]

However, "lack of knowledge of how to produce barleys for the malting trade is one of the greatest handicaps in malting barley production,"[23] and through numerous agencies efforts are being made to educate the grower to the problems involved. Without attempting to examine in detail the minute quality variations associated with the grading of malting barley, it will be worth while to indicate the major quality factors which determine the commercial suitability of barley for use in malting and the nature of those par-

[20] "The barley upon reaching the terminal markets is sampled, graded, and the grade with any special designations determined, after which a certificate is issued for the carload of barley. The grade, special class, and designations are indicated on the certificate as well as on the ticket placed in the barley sample. The barley is then offered for sale and is sold under the certificate issued for this particular lot of barley." Leith and others, *op. cit.*, p. 29.

[21] L. C. Burnett and Chas. S. Reddy: *Barley in Iowa,* Bull. 367, Iowa St. Coll., Agric. Exp. Sta., Ames, 1937, p. 274.

[22] U.S.D.A., *Yearbook, 1933,* Washington, 1934, p. 191.

[23] O. E. Barbee: *Barley Production in Washington,* Agric. Exp. Sta. Bull. 382, St. Coll. of Wash., Pullman, Wash., 1939, p. 43.

ticular farm operations which the attainment of that quality demands. Recognizing the fact that the established standards for Western Barley and for barley grown east of the Rocky Mountains are not the same, the enumeration of quality factors below has been made with special reference to the eastern area in which almost all of the domestic malting barley is produced.

MALTING VARIETIES

The quality factors which define the suitability of barley for malting are to a large extent associated with the inherent characteristics of particular varieties. Wide differences exist with regard to the ability of the several varieties to meet the requirements of the malting trade, and only certain definite types are capable of producing acceptable grain. Therefore, the selection of a suitable variety for cultivation is a prerequisite of the utmost importance.

Viewed in terms of the larger taxonomic groupings of the multitude of varietal forms of the barley plant, the place of the comparatively small number of varieties regarded as acceptable on the malting market is most precisely defined. A large number of barleys are immediately eliminated from consideration by the fact that the American maltster regards 2-rowed varieties as being undesirable.[24]

Among the 6-rowed varieties numerous additional limitations narrow the range of suitable types still further. For example, a wide variety of grain colors exists among the 6–rowed forms of barley, and the American market strongly prefers the white-kerneled types. Black barleys, like Lion, are not acceptable, and there is, among many American maltsters, a strong prejudice against blue-kerneled types such as Trebi.[25] The undesirable characteristics of producing a grain having loosely attached and easily frayed hulls, as is the case with Glabron,[26] and of being undependable with regard to producing a mellow grain, as is the case with Glabron and Trebi,[27] generally eliminate other forms of 6-rowed barley from malting classifications. Varietal suitability is also influenced by the diastatic power of the barley ker-

[24] It should be pointed out that the specific varieties and associated quality factors regarded as desirable by the American maltster are not held in similar favor throughout the world. While the recognition of the particular suitability of certain barley varieties for malting is in large measure dictated by practical considerations inherent in the malting process, the influences of taste preference and continuing adherence to traditional techniques are sufficiently strong to cause major differences in the defined quality standards of various nations. Whereas the American maltster has built his industry around the use of 6-rowed barleys, 2-rowed types are almost exclusively used for malt in central Europe, and in Great Britain the established practice involves the use of a mixture of domestic 2-rowed barleys with imported 6-rowed types. Jasny, *op. cit.*, p. 53.

nels, and here again certain 6–rowed varieties are found more desirable than others.[28]

An evaluation of all the varietal characteristics affecting malting quality has shown that the barleys capable of most adequately satisfying the demands of the American maltster are, without major exception, all members of one distinctive group of closely related types. This group is typified by the standard, 6-rowed, rough-awned, spring varieties, Oderbrucker and Manchuria, "around which the malting and brewing industries in this country were built."[29]

While Oderbrucker has maintained a position of high favor on the malting market and is still widely grown, the older Manchuria forms, including the closely related special Manchuria-type variety Odessa, are now grown on a steadily decreasing acreage. New, but related, higher-yielding, disease-resistant, or more conveniently handled varieties have appeared, especially during the last two decades, and the older Manchuria forms are rapidly disappearing from the farms. However, the fundamental character-

[25] The unfavorable position of blue barley on the malting market in the United States "persists despite the fact that the only American barley that is bought at a premium on the English market is the blue barley of the Pacific Coast. Indeed, when Atlas was introduced many English buyers complained that it was not blue enough" (U.S.D.A., *Yearbook, 1936,* Wash., 1937, pp. 310–311). Actually, as Harlan points out, "The blue color in itself is entirely harmless, being merely a pigment deposited in the outer layer of the endosperm. It has nothing to do with malting quality" (Harlan, Bull. 1732, *op. cit.,* p. 4). However, the presence of this color in barley grains is not always the reflection of a varietal characteristic. The appearance of a bluish tinge in the grains of white-kerneled varieties is regarded as an index of the undesirable condition of "steeliness." Since the blue color of the blue-kerneled varieties makes this recognition of a lack of mellowness difficult, many American maltsters refuse such varieties on the market (U.S.D.A., *Yearbook, 1936, loc. cit.*).

[26] Leith and others, *op. cit.,* p. 16.

[27] W. W. Brookings: *More Profits from Malting Barley,* Ext. Folder 68, U. of Minn. Univ. Farm, St. Paul, 1938, p. 3.

[28] "Diastatic power is a measure of the ability of the kernel to convert starch to malt sugar. Some barleys have enough diastase to convert readily much more starch than is contained in the kernel. Most brewers desire such barley. Good diastatic power is partially dependent on the size of the kernels and it is relatively greater in the smaller kernels. Large-kerneled barleys, such as Coast, Atlas, and the two-rowed sorts, have a large starch endosperm. The scutellum, the part of the embryo which secretes the diastase, is little larger than that found in the smaller kerneled barleys. Naturally, then, such small-kerneled varieties as Oderbrucker and Manchuria, particularly as grown in the upper Mississippi Valley, are relatively richer in diastase." (U.S.D.A. *Yearbook, 1936, op. cit.,* p. 310.)

[29] Dickson, *op. cit.,* p. 20.

istics of this strain still persist in large acreages of such high-yielding selections of older Manchurian varieties as Minnesota 184 and North Dakota 2121. Even more important are certain of the increasingly popular smooth-awned hybrid selections of the Manchuria type. Outstanding among these are Velvet and Wisconsin Barbless (Wisconsin Pedigree 37 and 38). The appearance and success of these new varieties of malting barley reflect the pioneering efforts of plant breeders to mold from the multitude of barley types, a plant of maximum desirability to both the farmer and the maltster.

The market classification of a given lot of barley as "Malting Barley" implies not only a freedom from specifically undesirable varieties, as is evidenced by the clearly stated regulation that "Malting Barley" shall contain "not more than 5 per cent of 2-rowed and/or other types or varieties of barley of unsuitable malting type such as Trebi and Black,"[30] but that mixtures of individually acceptable varieties are also regarded as undesirable. Even the accredited malting types display wide and distinctive differences with regard to their malting behavior, and mixtures lead to undesirable complications in the malting process.[31] The maltster regards the purity of varietal strains as an essential feature of malting quality, and farm programs have been instituted for the purpose of promoting the use of pure seed and a measure of sectional conformity with regard to the varieties raised.[32]

In the ensuing examination of the additional factors determining the suitability of barley for malting, it will be seen that nearly all of them are closely related to the specific potentialities of certain varieties. It must also be borne in mind that particular varieties are adapted to particular ecologic complexes, and the attainment of the desired quality of grain from any variety is dependent upon the presence of both seasonal and regional conditions favorable to its development.

KERNEL SIZE AND BUSHEL WEIGHT

One of the major market indices used in the classification of barley suitable for malting is a determination of the size of the individual grain kernels and their weight in bushel units. Medium-sized, well-filled kernels are

[30] *Handbook of Official Grain Standards of the United States,* Form 90, U.S.D.A., B.A.E., revised, Washington, D. C., 1937, p. 26.

[31] "Mixtures of rough- and smooth-bearded varieties are objectionable to maltsters as they possess different rates of germination, plumpness, mealiness, percentage of hull and other qualities, and are so variable that a uniform malt is not possible." W. W. Brookins: *Quality Production of Barley,* Ext. Pamp. 59, U. of Minn. Agric. Ext. Divis., St. Paul, Dec. 1939, p. 2.

[32] "With several varieties in a community mixtures are inevitable, and the marketing of uniform cars is greatly complicated." *Ibid.,* p. 2.

strongly preferred to inordinately large or slender sorts, since the plump kernel of moderate size "usually carries the desired proportion of starch and proteins."[33] The especially undersirable malting characteristic of a steely endosperm is commonly associated with the slim kernel.

Not only is conformance to a particular range of kernel size important, but the maltster demands a uniformity of size at some point within the desired limits. Kernels of different sizes display variations in their rate of germination, a fact which results in an undesirable lack of uniformity in the degree of starch conversion obtained during the malting process.

A reliable index to the desirably plump, well-filled nature of the barley kernels is afforded by the bushel weight of the grain.[34] The attainment of the desired kernel size and test weight per bushl is dependent upon at least three major factors: 1) the use of accepted varieties, 2) the proper care and attention on the part of the farmer in handling the crop, and 3) the presence of favorable ecologic conditions. Aside from selecting the proper variety, the farmer can considerably further his chances of obtaining an acceptably plump grain through judicious methods of soil fertilization,[35] careful soil cultivation, preparation of a good seedbed, early planting of the crop, and the elimination of competitive field weeds.[36] Care must also be exercised at harvest time, since light-weight, slender kernels may result from cutting the grain too early.[37]

No techniques on the part of the farmer, however, can attain the desired grain in the face of unfavorable ecologic conditions. As one group of authors points out in referring to the quality of kernel plumpness and acceptable bushel weight: "Barley to have these desirable points must be grown on clay or clay-loam soils having sufficient phosphorus and potash . . . . The season must also be favorable. Ample moisture with a cool summer insures a period of slow growth and maturity that is favorable for plumpness in barley. The occurrence of hot, dry weather just before the barley ripens, or when the kernel is filling out, causes a slim or slender kernel."[38]

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[33] Leith and others, *op. cit.*, p. 6.

[34] Under present grain standards "Malting Barley" must have a minimum test weight per bushel of 43 pounds, and Grade 1 "Malting Barley," a minimum test weight per bushel of 47 pounds. *Handbook of Grain Standards, op. cit.*, p. 27.

[35] "Plumpness may be improved by using suitable fertilizers," but precautions must be taken to avoid an excess of nitrogen, since soils too high in nitrogen increase the hazard of lodging and the subsequent shriveling of the grain. Brookins, *More Profits from Malting Barley, op. cit.*, p. 3.

[36] *Loc. cit.*

[37] Leith and others, *op. cit.*, p. 10.

[38] Leith and others, *op. cit.*, p. 6.

SKINNED AND BROKEN KERNELS

A third important factor in the definition of "Malting Barley" is associated with the measurable presence of skinned or broken kernels. Broken kernels, being unable to germinate, are of no value in malting and while they can be removed through screening and sold as feed, their presence represents a loss to the maltster.

Skinned kernels are even more objectionable because, unlike the broken kernels, they cannot be separated from the unskinned kernels by any method of screening, and because they either fail to germinate entirely, or do so at a retarded and unsatisfactory rate. Even in cases where the frayed hulls of the barley grains do not represent actual damage to the kernels' ability to germinate properly, "malt made from barley containing many frayed ends has a poor appearance and will not sell so well as malt made from barley with unbroken hulls."[39] Furthermore skinned kernels have the extremely undesirable undesirable character of being vulnerable to certain molds and fungi. As a result, under the official grain standards, barley which contains "more than 5 per cent of skinned and/or broken kernels," cannot receive a "Malting Barley" classification.[40] Kernel damage of this type results from too close threshing of the grain in an effort to improve its bushel weight.[41]

"DAMAGED BARLEY"

This quality factor has three important and distinct phases:[42] 1) damage resulting directly from fungous diseases, which may attack the grain either before or after it has been harvested; 2) damage caused by unfavorable weather conditions, particularly around harvest time; and 3) damage due to improper handling of the grain. The existence of any or all of these types of damage is usually betrayed by the color of the grain. A bright, "straw-colored barley invariably indicates that it was handled under good conditions, has not been weathered and is free from disease."[43]

Attacks of scab and Helminthosporium blight, which from the standpoint of malting quality are potentially ruinous, are one of the most serious problems with which the malting barley grower has to contend. The pres-

[39] Harlan, Bull. 1732, *op. cit.*, p. 3.

[40] *Handbook of Grain Standards, op. cit.*, p. 26.

[41] Brookins: *Profits from Malting Barley, op. cit.*, p. 4.

[42] In the grain trade the term "damaged barley" is used to designate "kernels and pieces of kernels of barley which are damaged or materially discolored by blight and/or mold, or which are heat damaged, sprouted, frosted, badly ground damaged, badly weather damaged, or otherwise materially damaged." To be classed as "Malting Barley" on the market, a given lot of grain must not include "damaged" kernels in excess of 4 per cent. *Handbook of Grain Standards, op. cit.*, pp. 26 and 35.

[43] Leith and others, *op. cit.*, p. 6.

ence of ecologic conditions, either seasonal or regional, favoring the development of these fungous diseases may make the growing of malting quality grain difficult, if not impossible. Proper cultural practices and the use of the least disease-susceptible varietal strains of barley can, however, be counted upon to reduce the hazards of serious blight damage.[44]

Aside from disease, the farmers' most important problem in avoiding grain damage is associated with taking all feasible precautions to prevent exposure of his crop to unfavorable weather conditions around harvest time. Frequent rains at this period are the particular hazard, and the matter of choosing the appropriate time for cutting the grain is a difficult one.[45] Obviously the longer the grain is allowed to stand in the field, the greater the danger from storm and moisture damage becomes, but the farmer must be careful that in his anxiety to get his grain in that he does not cut it too early, for when cut before fully ripe the barley will be lacking in other desirable malting qualities.[46]

Efforts to improve the color of stained or blighted barley through the 'use of sulphurous acid or any other bleaching agent" results in a market classification of "Bleached Barley."[47] Since bleached kernels are usually dead, their presence eliminates a given lot of grain from any possibility of being placed in a malting grade.

GRAIN MELLOWNESS

Mellowness, or the quality in opposition to what is known in the malting trade as steeliness, is an important, though perhaps the most intangible, feature of high grade malting barley. The mellowness of barley kernels is associated with their starchiness. "When starch is formed in the kernel, there are many intermediate products. These halfway materials constitute a large percentage of the solids of the kernel in the early stages of growth. As the kernel develops these products constitute less and less of the total weight and in a fully mature well-ripened kernel, they are negligible. Any barley kernel in which growth is interrupted will be 'steely,' that is, hard, with small-sized starch particles and intermediate products that dry down to a flinty mass. Such interruptions may come from disease, from drought, or, in humid climates, from hot weather."[48]

The previous discussion of the malting process clearly indicates the rea-

[44] Brookins: *Profits from Malting Barley, op. cit.*, p. 4.

[45] Harlan, Bull. 1732, *op. cit.*, p. 5.

[46] Leroy Powers and others: *Barley in Minnesota*, Spec. Bull. 135, Revised, U. of Minn., Agric. Ext. Divis. St. Paul, July, 1934, p. 9.

[47] *Handbook of Grain Standards, op. cit.*, pp. 35 and 26.

[48] D. D. Hill and others: *Barley Production in Oregon*, Bull. 355, Oregon St. Coll., Agric. Exp. Sta., Corvallis: June, 1938, p. 27.

son for the maltsters' preference for the mellow grains of barley. The starchy soft-textured kernels absorb water more readily and germinate more rapidly and uniformly than those that are steely and hard.[49]

The attainment of a satisfactory degree of mellowness "is largely dependent on the fitness of the variety to the region in which it is grown."[50] Assuming that proper attention has been given to this factor, and in the absence of disease, maximum grain mellowness may be expected to result from the occurrence of a favorable season, in which a cool ripening period has not hastened plant growth,[51] and in which development has not been suddenly arrested by drought, in combination with the desirable cultural practices of not cutting the crop before it is fully ripe and stacking the grain before threshing.[52]

GERMINATION AND FREEDOM OF GRAIN FROM IMPURITIES

Since the making of malt is accomplished through the controlled germination of the barley kernels, it is clear that the maltster must have a grain with both "high and uniform germinating power."[53] Kernels that fail to germinate entirely are a total loss, and a lack of uniformity in the germination of those kernels capable of sprouting, results in variations in the degree of starch conversion during the malting process and the consequent production of a low-quality malt.

Materials other than barley, that may become mixed with the grain prior to its arrival at the market, reduce the value of any given shipment in direct proportion to the weight percentage of their occurrence.[54] The weight loss resulting from the removal of "dockage" may be excessive in the case of poorly cleaned grain, and the presence of more than 3 per cent of "foreign material" eliminates a given lot of grain from even the lowest grade classification of malting barley.[55]

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[49] To attain a malting classification on the market, a shipment of barley must conform to the stated regulation of containing "75 percent or more of mellow barley kernels which kernels are not, en masse, semi-steely." (*Handbook of Grain Standards, op. cit.*, p. 26.)

[50] U.S.D.A., *Yearbook, 1936, op. cit.*, p. 309.

[51] Leith and others, *op. cit.*, p. 6.

[52] Harlan, Bull. 1732, *op. cit.*, p. 5.

[53] Leith and others, *op. cit.*, p. 7.

[54] Two classes of such impurities are recognized by the grain trade: 1. "dockage," which "includes weed seeds, weed stems, chaff, straw, grain other than barley, sand, dirt, and any material other than barley, which can be removed readily from the barley by the use of a metal scalper riddle sieve . . . ," and 2. "foreign material," which includes "all matter other than barley, except other grains, wild oats, and smut masses, which is not separated from the barley in the proper determination of dockage." (*Handbook of Grain Standards, op. cit.*, pp. 30 and 35.)

[55] *Ibid.*, p. 27.

REGIONAL ORIENTATION OF AMERICAN MALTING BARLEY PRODUCTION

The preceding examination of the exacting grain-quality requirements of the domestic malting trade has shown that the production of barley suitable for the American maltster is dependent upon at least three major considerations: 1) the cultivation of particular varieties having certain definite and desirable inherent potentialities; 2) the presence of those specific ecologic conditions which, in combination, most nearly provide optimum conditions for grain development and harvesting; and 3) the utilization of planned cultural techniques on the part of the grower. Having stated and described the character of these outstanding factors, it now becomes a matter of geographic significance to evaluate their influence in determining the current areal pattern of malting barley production in the United States.

While certain regional, and in some cases associated racial, differences in the ability or willingness of the grower to conform to particular farm practices may be claimed to exist throughout the United States, it seems fair to assume that the part played in the production of suitable malting barley by the adherence of the farmer to specific cultural techniques has had little or no influence on the major distributional patterns associated with the growing of malting barley. The application of approved methods of cultivation may certainly be considered to be primarily a matter of grower-education in those regions, which, through much more profound influences, have been determined to be suitable for the production of this particular type of quality grain.

The factors which, from the regional point of view, are definitive, are based upon the closely inter-allied influences associated with varietal character and ecologic conditions. As has already been emphasized, the production of acceptable malting barley is impossible unless certain varietal forms of the plant are cultivated in regions having the ecologic conditions to which each variety is specifically adapted. Furthermore, certain features of grain quality, other than those attained through the cultivation of particular varieties in areas suited to their development, are intimately tied up with the ecologic character of the region and season in which the grain has been grown. Clearly then the practical influences of these interrelated facts will create a definite regional localization of the production of malting barley.

Using the above information one may almost deduce logically the position of this regional localization. In this connection, attention is directed to the following interrelated considerations:

1. The production of a barley having qualities considered most suitable by the American maltster, involves the cultivation of one of the several acceptable varieties of the Manchuria-Oderbrucker type.

2. The region which most nearly provides conditions of ecologic optimum for the varieties of this type, and, as a consequence, is characterized by a dominance of the Manchuria-type varieties, is located in general in Michigan, Wisconsin, Minnesota, eastern North and South Dakota, and northern Iowa and Illinois (see Fig. 1).[56]

3. Within this somewhat extensive primary region, defined largely by climatic considerations, there are several outstanding areas that reflect by their position the presence of specifically favorable edaphic conditions. These areas of concentration represent the most ecologically favorable districts in the entire country for the cultivation of Manchuria-type barleys.[57] The outstanding areas are found in the counties of western Minnesota and eastern North Dakota (the Red River Valley), southwestern and southeastern Minnesota, southeastern South Dakota, northwestern Iowa, northeastern Illinois, eastern Wisconsin, and eastern Michigan (the Thumb district).

4. Apart from the varietal limitations imposed by the market, and the associated areal limitations of cultivation imposed by the ecologic requirements of the accredited varieties, there is the additional consideration of the quality factors affected by environment per se. In recognition of this phase of the problem, the statement is made that with regard to the desired development of such factors as germinating power, diastatic power, and protein content, "the best malting barley is produced on the borderline between drier and moister regions."[58]

5. In conclusion it should be pointed out that, while the existing ecologic conditions are less favorable for the quality production of Manchuria-type grain in the spring barley district to the east of Michigan, this region in general, and western New York state in particular, is capable of producing acceptable malting barley. Here, however, social and economic pressures in a dynamic history of development have largely eliminated any stimulation of important production.[59]

In the light of the material presented above, the distributional patterns revealed in the maps which follow may be viewed as a basis for interpretative understanding. It would certainly seem reasonable to suppose that a barley capable of satisfying the special demands of the American maltster could not be grown on a large scale anywhere in the United States, except in

[56] The indebtedness of the author to Prof. James G. Dickson, of the University of Wisconsin College of Agriculture for aid in the delimitation of the necessarily generalized regions of varietal dominance shown in Figure 1 is gratefully acknowledged.

[57] See John C. Weaver: Climatic Relations of American Barley Production. *Geogr. Rev.*, Vol. 33 (1943), No. 4, pp. 569–588.

[58] Jasny, *op. cit.*, p. 520.

[59] See John C. Weaver: Barley in the United States: A Historical Sketch, *op. cit.*

the highly suitable and well-known barley districts within the Manchuria-type varietal region of the North Central States (see Fig. 1).[60]

MARKET CENTERS FOR MALTING BARLEY

To verify these deductions, and for the purpose of obtaining a more refined picture of existing distributional patterns, an attempt was made to assemble such available market data as might be expected to provide a reliable basis for mapping the origin areas of the barley used by the domestic malting industry. An investigation revealed that the Federal Grain Supervisors at the several principal grain markets had, since 1935, been conducting a series of periodic surveys designed to show the county origins of all cars of barley received at the principal terminal markets, which were, subsequent to their arrival, graded "malting." The assemblage of these data from the unpublished survey reports provided the basis for preparing the original maps shown in Figures 2–8.[61]

The four principal markets receiving barley for use in the American malting industry are situated in: Minneapolis, Duluth-Superior, Milwaukee, and Chicago. Relatively much smaller quantities of domestic malting bar-

[60] The American region which for almost a century has been the most outstanding producer of malting barley for foreign markets, and the only region in which post-Prohibition years has maintained significant exports of malting grain, is the Pacific Coast. Some of the barley entering the international grain trade from this region comes from the dryland and irrigated areas of eastern Oregon and Washington, as well as from the Willamette Valley and Puget Sound Trench, but by far the largest percentage of the total originates in the San Joaquin and Sacramento Valleys of interior California. The high quality Western Barleys produced in these areas, while used to some extent locally for malting, are in general regarded by most American maltsters as being less desirable than the Manchuria-type grains produced in the north central area.

The Coast types of barley raised in the far western states in general, and the Atlas variety, grown largely in the interior valleys of California, in particular, are held in especially high repute and find a consistent demand on the English market. In Great Britain, the only important European nation that does not exclusively utilize 2-rowed barleys for malting, the established malting practices call for a mixture of domestic English "two-row barleys with a certain percentage of six-row barleys raised under dry conditions with a great deal of sunshine (the so-called sunshine barleys), in order to offset the extremely low diastatic power of the barleys grown in that foggy country. Californian barley of high quality is the type mostly used for this purpose." (Jasny, *op. cit.*, p. 53.)

[61] So far as the author is aware these maps represent the first attempt at an accurate and complete cartographic representation of such data. The collection of these data was made possible through the generous offices of Professor James G. Dickson of the U. of Wisconsin, College of Agriculture, to whom the writer wishes to express his sincere appreciation. The author also wishes to acknowledge the sympathetic and understanding aid, given both in conference and by letter, of the following Grain Supervisors of the U.S.D.A., Agric. Marketing Service, Office of Federal Grain Supervision: Mr. M. J. Johnson, Minneapolis, Minn.; Mr. W. H. Shea, Duluth, Minn.; Mr. C. L. Cannon, Chicago, Ill.; and Mr. F. A. Cummings, Milwaukee, Wisconsin.

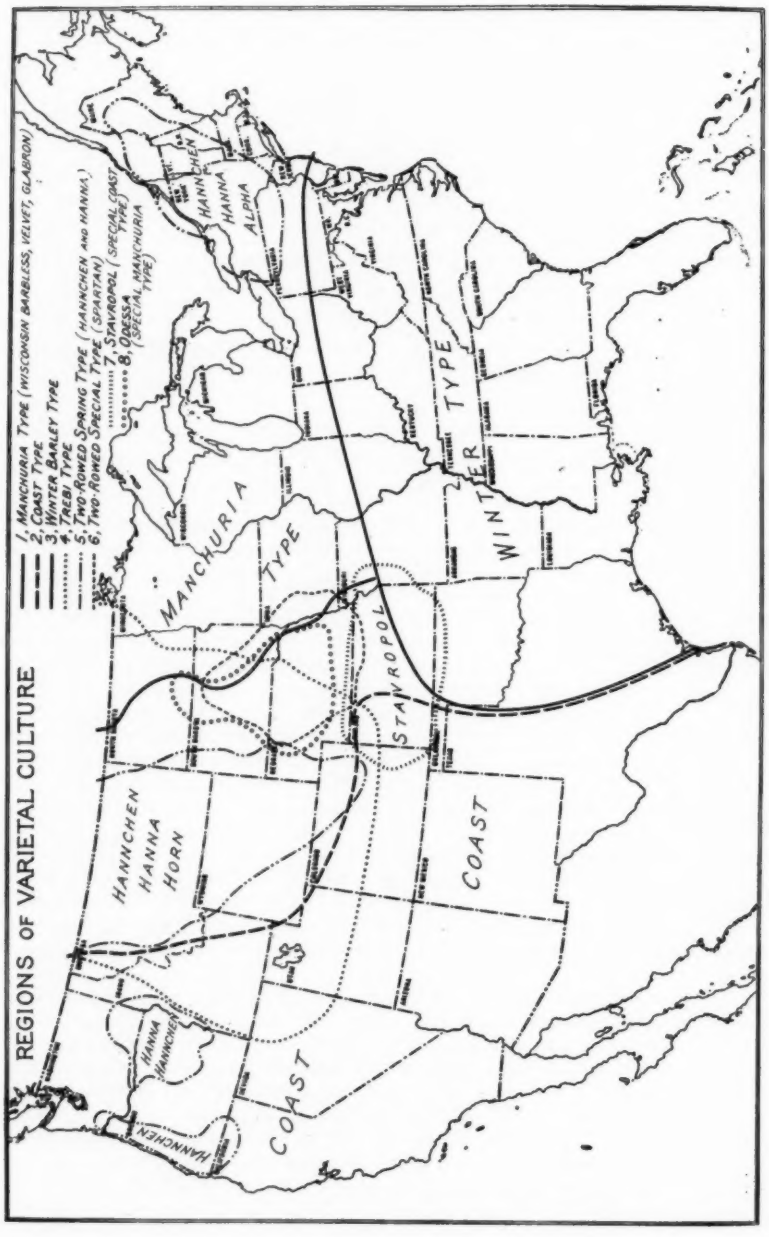

FIG. 1.—Regions of barley varietal dominance in the United States.

ley are received at markets in Omaha, Detroit, Toledo, and Buffalo, while comparatively insignificant amounts are shipped to St. Louis, Peoria, Cedar Rapids, and Sioux City terminals.

It was decided that the basic patterns of distribution might best be established by first mapping the data, in so far as they were available, relating to the points of origin of all malting barley received at the principal markets in the course of one normal pre-war year. Since the movement of barley to the markets from country shipping points begins with the harvesting of the crop in July, and proceeds throughout the ensuing 12-months period, this involved a collection of the data pertaining to receipts, recorded by months, for each market, and a subsequent totaling of the monthly figures to obtain the full amount received from each county following the crop harvest of one particular season.

In assembling the data concerning the county origin of the barley graded "malting" at the several markets, it was found that the dominance of the four major markets was so strong as to make an investigation of the materials relating to the smaller terminals unnecessary. An intensification but not a refinement of the fundamental patterns revealed by the mapping of the Minneapolis, Duluth-Superior, Milwaukee, and Chicago data, could be gained through a representation of similar statistics from the less important markets. Complete, or approximately complete, monthly records for an entire July to June crop-shipping year were available for these four markets for only the one year, 1939–1940. Fortunately the crop year of 1939, and the subsequent shipping-year 1939–1940, may be recognized as adequately representative, both as regards the quantity of malting barley moved and the distribution of points of origin.[62] For the Minneapolis and Duluth-Superior markets the data for the full crop-shipping year were complete. In the case of the Milwaukee market, data for the two months, May and June, were not obtained, and in the case of the Chicago market, figures for the three months, May, June, and July, were lacking. However, generally smaller amounts of barley are shipped in the three months of May, June, and July, than in any other months of the year, and the absence of these data may be regarded as having had no appreciable effect on the character of the maps.

The collected data for the year 1939–1940 were mapped for each of the four principal markets separately (Figs. 2–5). This procedure was employed in preference to combining the information in one map, since by having four maps it was possible to use a more detailed scale of dots and thereby to portray the distributional patterns in a higher degree of refinement, and also because the distinctive association of specific areas with par-

[62] M. J. Johnson, in conference with the author, May, 1940.

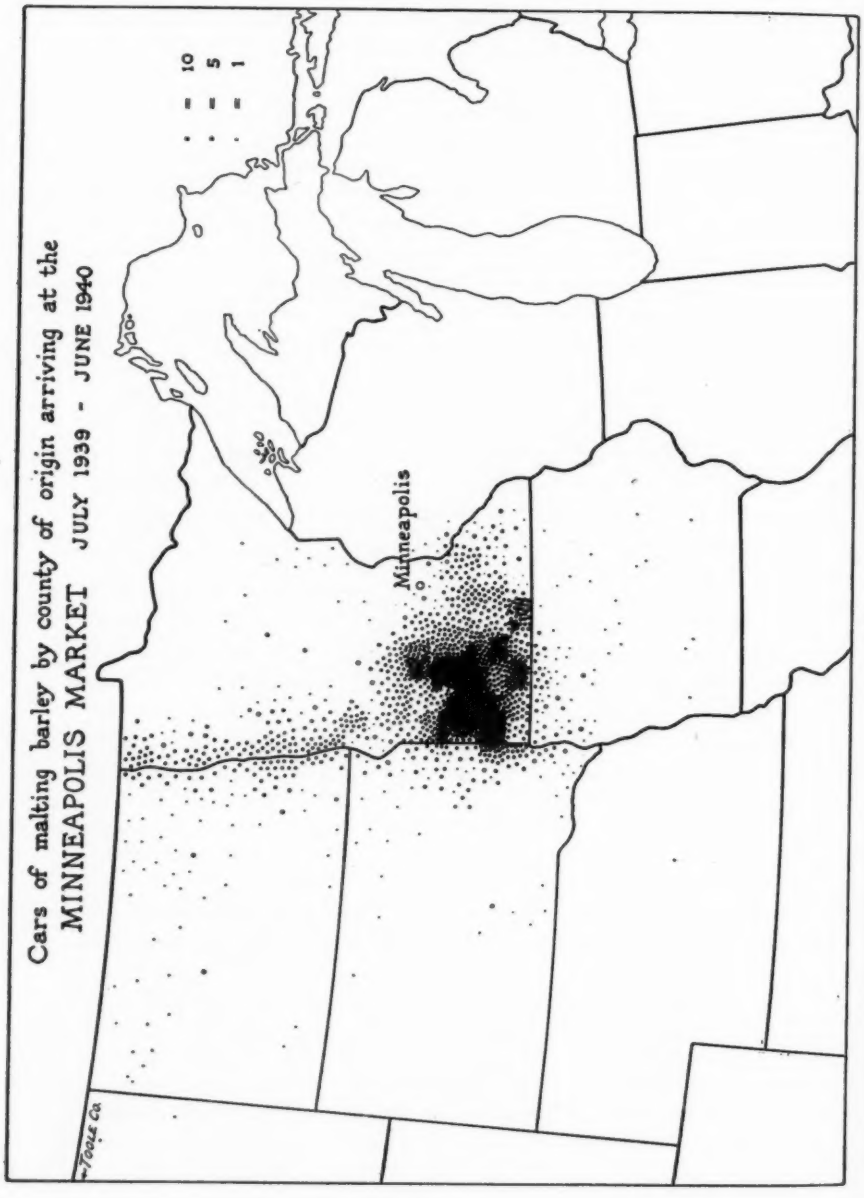
Cars of malting barley by county of origin arriving at the
MINNEAPOLIS MARKET JULY 1939 - JUNE 1940
• = 10
• = 5
• = 1
Minneapolis

FIG. 2

ticular markets seemed to have a geographic value worthy of recognition. An examination of the four maps together will clearly reveal the fact that every one of the outstanding barley-producing areas in the Manchuria-type varietal region of the North Central States,[63] makes a contribution of some importance to one or more of the four principal markets. It will also be noted that the shipment of malting barley from areas beyond the limits of the Manchuria-type varietal region, designated in Figure 1, is almost negligible.

THE MINNEAPOLIS MARKET

Certainly the most outstanding fact revealed in Figure 2 is the very great importance of southern, and especially southwestern, Minnesota, in the production of malting barley. In the period from July 1939 to June 1940, more than 2,000 cars[64] of acceptable malting barley were received on the Minneapolis market from Redwood and Lyon counties alone. Extremely large shipments also originated in such other southwestern counties as Renville (624 cars), Kandiyohi (519 cars), Murray (517 cars), Pipestone (483 cars), Brown (455 cars), Jackson (412 cars), Yellow Medicine (402 cars), Cottonwood (360 cars), and Watonwan (356 cars). Not only does Figure 2 disclose the extreme importance of the southwestern Minnesota counties in providing malting barley for the Minneapolis market, but a comparison of Figure 2 with Figures 3, 4, and 5 shows that the production of this area strongly outranked that of any other north central district in this year.

As Figure 2 shows, some barley of malting quality is received at the Minneapolis market from nearly all parts of Minnesota, with the smallest quantities coming from the relatively poor and largely non-agricultural cut-over lands of the north-central and northeastern parts of the state. Next to those of the southwest, the south central, southeastern, and Red River Valley counties of Minnesota make the most important contributions to the Minneapolis market. The largest shipments from these areas in 1939–1940 originated in: Faribault (385 cars), Blue Earth (284 cars), and Sibley (251 cars) counties in the south central area; Goodhue County (183 cars) in the southeast; and Wilkin (200 cars), Clay (194 cars), Grant (186 cars), Polk (180 cars), and Kittson (173 cars) counties in the Red River Valley area.

The total volume of the malting barley consignments arriving on the Minneapolis market from points outside of Minnesota is shown to be comparatively small. In North Dakota, high-quality barley production appears, as might be expected, to be largely centered in the Red River Valley to the

[63] See maps in John C. Weaver: Barley in the United States: A Historical Sketch, *op. cit.*

[64] One carload of barley contains on the average of 1500–2000 bushels. M. J. Johnson, in conference with the author, May, 1940.

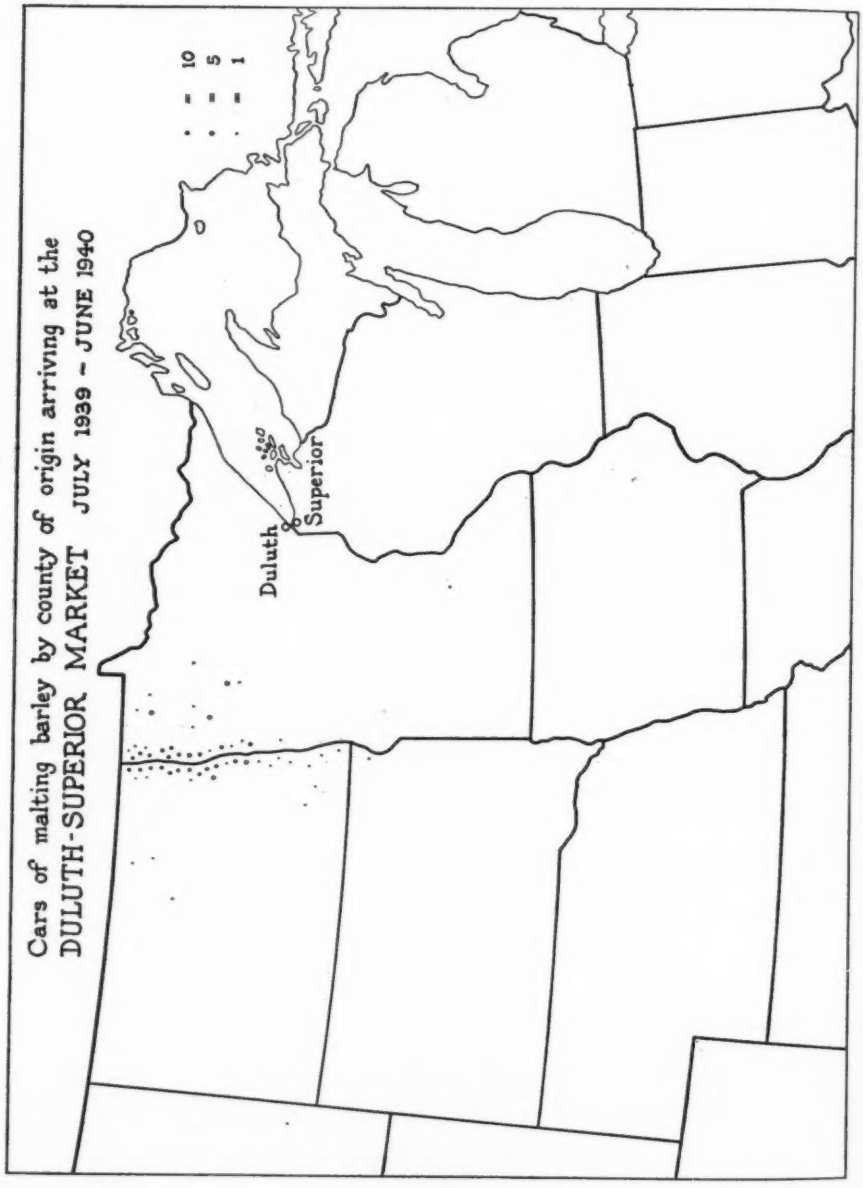
Cars of malting barley by county of origin arriving at the
DULUTH-SUPERIOR MARKET JULY 1939 - JUNE 1940
= 10
= 5
= 1
Duluth
Superior

FIG. 3

east, with scattered small shipments originating in the northern counties as far west as the Montana border. With a total shipment of 224 cars, Cass County, lying largely in the Red River Valley, made by far the largest contribution.

As the Minneapolis market records clearly indicate, the production of malting barley in South Dakota is also generally confined to the eastern part of the state, the counties adjacent to the all-important southwestern Minnesota area making the largest shipments. Moody (222 cars) and Minnehaha (168 cars) counties are outstanding.

Figure 2 shows that the Minneapolis market draws some grain from the high-quality barley growing districts of northwestern Iowa, but the total volume is relatively small. Dickinson County with a shipment of 74 cars, and Lyon with 41, accounted for a large percentage of the amount received from this area. Small, scattered shipments were also received in 1939–1940 from central Iowa, the Wisconsin counties close to Minneapolis, central Nebraska, and eastern Montana.

THE DULUTH-SUPERIOR MARKET

Figure 3, showing the points of origin of malting barley shipments arriving on the Duluth-Superior market during the year 1939–1940, presents a marked contrast to Figure 2, both with regard to the total volume of grain received and with regard to the extent and position of the source regions. The actual quantity of grain received on the Duluth-Superior market is obviously insignificant when compared with the Minneapolis receipts. Redwood County in southwestern Minnesota, for example, contributed more than four times as much malting barley to the Minneapolis market in that year, as all the counties contributing to the Duluth-Superior terminal combined. Furthermore, it is interesting to note that while the Minneapolis market draws upon the malting barley production of extensive areas in several states, shipments to the Duluth-Superior market originate almost exclusively in a single narrowly defined region along the border between two states.

These contrasts are largely explained by the geographic positions of the two markets and the associated nature of the transportation facilities by which they are connected with the producing areas. Rail shipments from all of the major barley-growing areas in the North Central States, with the single exception of the northern portion of the Red River Valley, have the advantage of a shorter, or at least more direct, haul to principal market terminals other than Duluth and Superior. And even in the Red River Valley, mainline rail service tends to lead products southeastward toward Minneapolis.

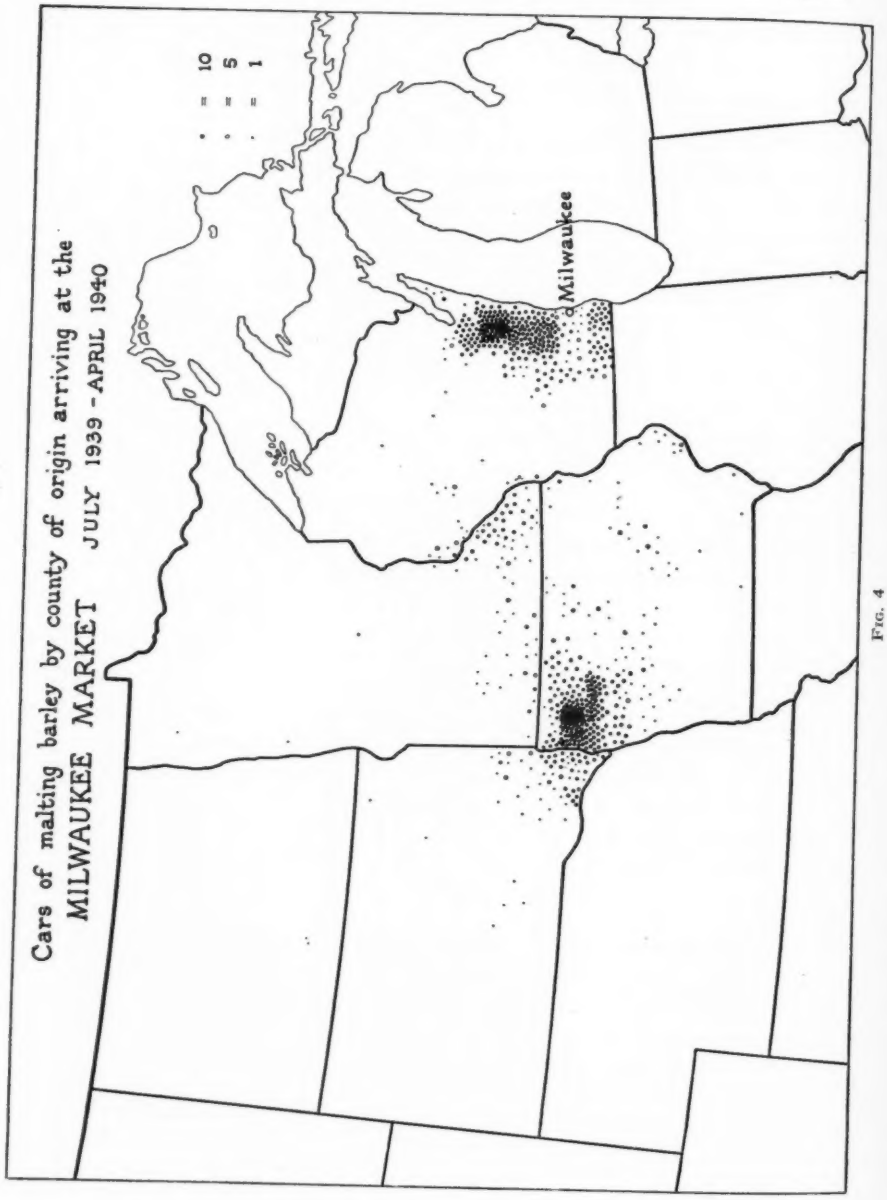
Cars of malting barley by county of origin arriving at the
MILWAUKEE MARKET JULY 1939 - APRIL 1940
10
5
1
Milwaukee

FIG. 4

Of the 273 cars of malting barley arriving on the Duluth-Superior market in this year, the major part was divided about equally between the valley counties on the two sides of the Red River. The largest quantities were drawn in both instances from the three most northerly counties: Pembina (32 cars), Walsh (30 cars), and Grand Forks (46 cars) on the North Dakota side; Kittston (33 cars), Marshall (40 cars), and Polk (27 cars) on the Minnesota side. However, while the total Red River Valley shipment to the Duluth-Superior market is admittedly small when compared to the volume moved from other areas to alternative markets, Figure 3 does, when considered in combination with Figure 2, serve to emphasize the aggregate importance of this region in the production of malting-quality barley.

THE MILWAUKEE MARKET

A cartographic representation of the data pertaining to the points of origin of malting barley receipts for the year 1939–1940 at the Milwaukee market (Figure 4), reveals the primary importance of certain areas which either failed to appear entirely, or were at least relatively unimportant, in the records of the markets previously examined. Eastern Wisconsin and northwestern Iowa are outstanding, while southeastern Minnesota and extreme southeastern South Dakota may be recognized as secondary centers of considerable significance.

Considering both the extent of the area involved and the total quantity of grain contributed to the market, it is clear that eastern Wisconsin ranks second only to southwestern Minnesota as a region of malting barley production. With regard to the consistent year-after-year production of high-quality malting grain, it is doubtful whether any other American area possesses a record the equal of this one. The largest shipments in the 1939–1940 period, a year which may be regarded as normal in this region, originated in the counties to the south, southeast, and east of Lake Winnebago: Fond du Lac (331 cars), Calumet (312 cars), Washington (264 cars), Manitowoc (248 cars), Dodge (245 cars), and Sheboygan (198 cars). Although the counties directly west of Milwaukee, having large areas of poorly drained soils, produce only relatively small quantities of high-quality barley, a distinctly important contribution of malting grain is made from the fertile prairie-soil areas in the southeastern corner of the state. Whereas in the 1939–1940 crop-shipping year, only 39 cars of malting barley were received on the Milwaukee market from Waukesha County, and only 17 cars from Jefferson County, 116 originated in Kenosha County, 114 in Walworth, and 105 in Racine.

As Figure 4 indicates, large shipments of malting grain were received at Milwaukee from northwestern Iowa. While the contributing region is

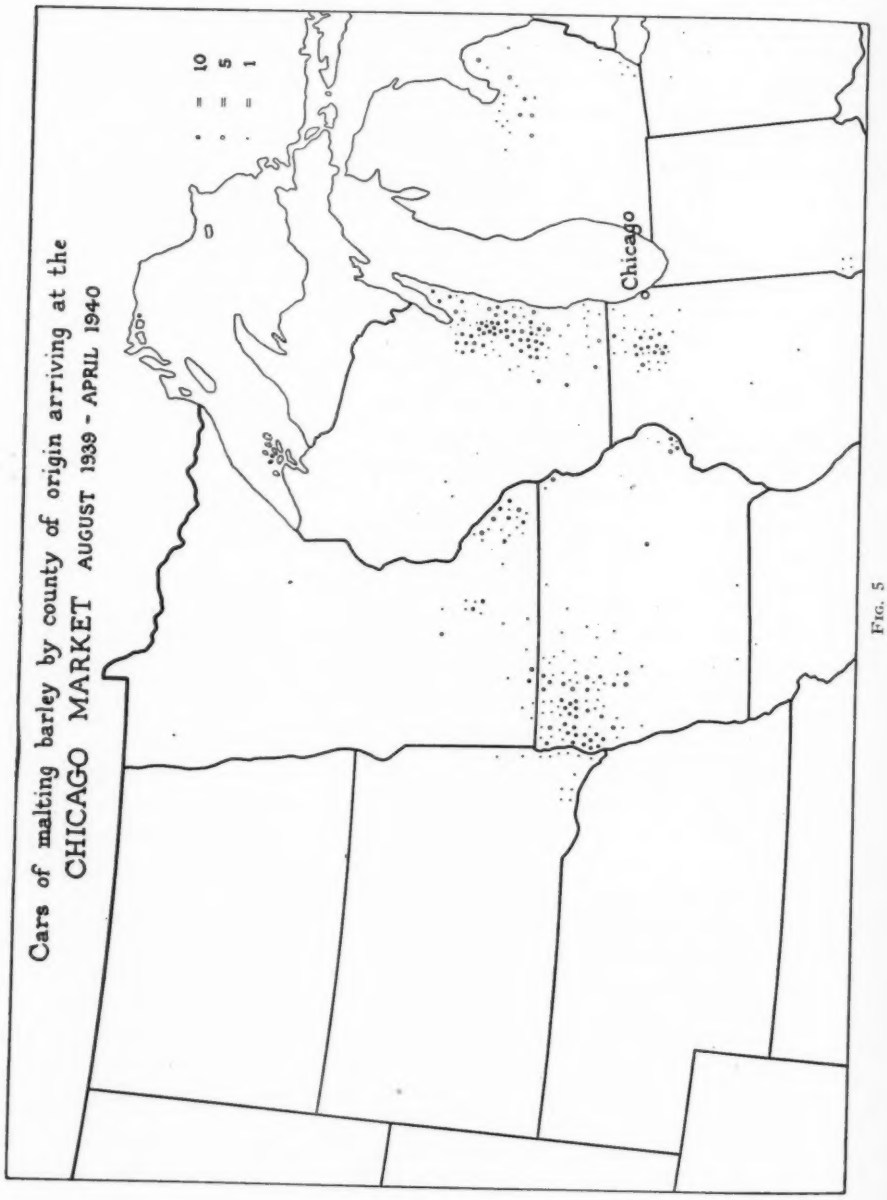
Cars of malting barley by county of origin arriving at the
CHICAGO MARKET AUGUST 1939 - APRIL 1940
10
5
1
Chicago

FIG. 5

smaller than that in Wisconsin, the ratio between the total volume of grain shipped and the size of the potential production area is extremely high in a few counties. O'Brien (406 cars), Sioux (397 cars), Cherokee (237 cars), Buena Vista (224 cars), and Plymouth (222 cars) counties are outstanding. It will be noted that the extreme northern tier of counties in the northwestern corner of the state, which makes substantial contributions to the Minneapolis market, ships relatively smaller quantities of barley to Milwaukee. This is undoubtedly explained, at least in part, by the existence of a more direct mainline rail service northward in this area.

The southeastern South Dakota counties, adjacent to the area in Iowa referred to above, and in large part south of the eastern South Dakota area drained most heavily by the Minneapolis terminal, have a significant place on the Milwaukee malting barley market. The largest shipments received in this particular year originated in Lincoln (91 cars), Union (84 cars), and Yankton (72 cars) counties.

In Minnesota the influence of somewhat distant out-of-state malting barley markets is felt only in the southern, and particularly southeastern, counties, where through rail service tends to draw such farm products toward southeastern terminals. The largest quantities of Minnesota barley reaching the Milwaukee market originated in the southeastern counties of Winona (70 cars), Wabasha (62 cars), and Olmstead (44 cars).

THE CHICAGO MARKET

The distributional patterns revealed in Figure 5, showing the points of origin of malting barley arriving on the Chicago market, serve both to reemphasize the importance of certain contributing areas already recognized through their association with other terminals, and to indicate the position and relative importance of those producing districts which have not appeared in the previouslly examined market records. In the former category, eastern Wisconsin, southeastern Minnesota, and northwestern Iowa are outstanding, while east central Michigan, northeastern Illinois, and Scott County, Iowa, are areas having an especial interest in the latter connection.

The importance of eastern Wisconsin in the production of suitable malting barley, already strongly defined in the Milwaukee market reports, is clear when one examines Figures 4 and 5 together. In addition to the large above-mentioned shipments made from the east central counties to the Milwaukee market in the 1939–1940 year, substantial quantities of malting grain were sent to the Chicago market from Calumet (93 cars), Fond du Lac (75 cars), Dodge (72 cars), and Outagamie (67 cars) counties. It is an interesting and not easily explainable fact that the much more conven-

iently located counties in the southeastern corner of Wisconsin, recognizable from the Milwaukee records as important producers of malting barley, should supply such relatively insignificant amounts of this grain to the Chicago market.

As a comparative examination of Figures 2, 4, and 5, shows, northwestern Iowa is the only area making really large separate contributions to three of the four major markets. Its crossroads position with relation to through north-south and east-west rail service, and its lack of nearness to any of the leading terminals, probably serve as explanations of this fact. The more important shipments from this area to Chicago in the year 1939–1940 originated in O'Brien (72 cars), Plymouth (71 cars), Sioux (52 cars), Dickinson (31 cars), Buena Vista (28 cars), and Sac (26 cars) counties.

Minnesota barley arriving on the Chicago market came largely from Winona (36 cars), Le Sueur (24 cars), and Fillmore (19 cars), counties in the southeastern portion of the state, and from Jackson (17 cars) County in the southwest. As the map shows, a few carloads of grain also reached the Chicago terminal from the previously discussed counties of southeastern South Dakota.

Shipping only to the Chicago market among the major terminals, the barley-growing region of northeastern Illinois appears in Figure 5 to have a place in the production of malting-type graain. The largest amounts originated in this year from the two counties immediately west of Chicago, De Kalb (78 cars) and Kane (33 cars).

While the Chicago receipts do indicate the presence of a malting-barley region in the Saginaw Valley-Thumb section of eastern Michigan, they do not reveal the quantitative importance of its production. A large percentage of the malting grain shipments originating in this region are sold on the more conveniently located markets in Detroit, Toledo and Buffalo. Almost half of the total amount of Michigan barley shipped in this year to Chicago came from Saginaw County (25 cars).

When compared with other counties and areas contributing malting barley to the Chicago market, the 27 cars received from Scott County seem relatively unimportant. In fact, even if these shipments be considered in combination with the additional 8 cars sent to Milwaukee, the county does not appear to be outstanding. However, in view of the fact that Scott County is situated outside of the region of ecologic optimum for spring barley, and in the light of the historical importance of its production, these shipments take on a particular significance in reflecting an agricultural survival of racial preferences and techniques.[65]

[65] The early mid-Nineteenth century importance of barley production in Scott County was based largely on the presence of a predominately German population.

AREAL POTENTIALITIES IN THE NORTH CENTRAL REGION

In the foregoing examination of the maps showing the distribution of the points of origin of barley graded "malting" on the principal markets, it has been apparent that the production of this type of high-quality grain is confined to a relatively small number of specific areas. Fundamentally the positions and limits of these areas, as defined by the 1939–1940 crop-shipping season, are a reflection of similar positions and limits of complexes of ecologic conditions peculiarly suited to the production of this rigidly designated type of grain quality.

The suitability and limits of the north central region, within which all of the important domestic production of barley of malting quality is concentrated, is defined primarily by climatic considerations, and in a measurable degree by a group of closely associated biologic factors. The particular areas of production concentration reflect the somewhat more localized occurrence of favorable edaphic conditions within the larger region of climatic suitability.

One somewhat obvious but none the less important observation must be made, however, with regard to these ecologically defined areas within the north central region. While the edaphic conditions which have largely delimited the areas may be regarded as reasonably permanent and stable attributes of the several areas, assuming of course that the soils are properly managed, climatic considerations are seasonally variable. The presence of these areas within a region of specified climatic suitability suggests that the occurrence of favorable seasons may here be more regular than in any other region, but no area will *every year* experience the same, or even a suitable, combination of meteorological conditions in all growing seasons. The desired periodicity and character of the weather elements are in reality unpredictable variables, and consequently the ecologic suitability of these particular areas for the production of malting barley must not be regarded as a constant actuality but rather as a significant potentiality.

Certainly, as might be expected, the occurrence of meteorologically favorable growing seasons over the suitable soil areas will be most regular near the heart of the major climatically defined region, and most variable near its outer margins. For example, while favorable seasons are likely to permit the production of desired grain quality in eastern Wisconsin in almost every year, southeastern Minnesota may be capable of producing such barley on an average of three years out of four, southwestern Minnesota two or three years out of four, and areas in the eastern Dakotas only one or two years out of four. Some areas situated beyond the limits of what is considered to be the north central malting-barley region may, over longer

periods of time, experience an occasional season which leads to the development of marketable malting grain.

It so happens that the growing season of 1939 favored the production of malting-quality barley throughout almost the entire north central region, and the previously analyzed maps, showing the movement of that year's crop to the major terminal markets, revealed the position of all of the outstanding *potential* production areas. This is not the case, however, in all years. As a result of locally unfavorable seasons, the grain of all or parts of any of the several areas defined in Figures 2–5, may in certain years be of such a quality as to fail to find a place on the malting markets. The purchasers of malting barley keep a constant watch over all of the *potential* areas, drawing each season upon the district or districts which in that year have experienced the most favorable conditions. This year an agent "is buying malting barley perhaps in northern Illinois, next year perhaps in South Dakota, searching always for the best for his purpose."[66]

On the basis of the frequency with which particular areas produce barley of desired quality, strongly established district reputations gain recognition on the market, and their importance must not be overlooked. For example, the eastern counties of North and South Dakota are situated near the dry margin of the region climatically suited for the growing of malting-quality barley, and in many seasons flinty or steely types of grain are produced. As a result, Dakota barley has assumed an unfavorable reputation among many maltsters, and even in the admittedly frequent years when high-quality grain is produced in these states, greater difficulty is experienced in finding it a place on the market than would be the case had it originated in more highly regarded areas. It is a well-recognized fact that the saleability of a carload of barley is sufficiently affected when bearing a tag showing a Dakota origin, that many eastern Dakota growers truck their grain to rail shipping points across the state lines in Minnesota and Iowa for the purpose of having non-Dakota points of origin assigned to their shipments.

It should, of course, be recognized that district reputations are built up not only on the basis of the areal frequency of favorable growing seasons, but also through the degree of grower adherence in a particular section to the accredited techniques of production. As one writer states: "The reputation of country shipping points for dependability and quality creates a demand for their barley on the terminal markets. Country elevator operators should encourage farmers to produce a uniform, high-quality product and to have their barley inspected regularly for those factors which can be controlled. If low-quality grain goes to the market, lower prices result and the entire community suffers."[67]

[66] U.S.D.A., *Yearbook, 1936, op. cit.*, p. 305.

[67] Brookins, *More Profits from Malting Barley, op. cit.*, p. 6.

In order to examine the existing year-to-year variations in the actual performance of the potential producing areas, Figures 6-8, showing the points of origin of malting barley arriving at the principal markets in portions of three different crop-shipping years, have been prepared. It will be noted that these three maps, relating to the years 1935, 1938, and 1939, differ from Figures 2–5 in two essential particulars: 1) Because of the lack of additional available data, these maps do not represent shipments for a full crop-shipping year, but only for the two months, August and September. In the official surveys prepared by the Federal Grain Supervisors, data were assembled for these two months because so large a percentage of the total shipment of one year takes place in August and September, that it was believed fair to assume that conditions in these months provided an accurate and reliable picture of distributional patterns which could be intensified but not refined through a representation of data for the entire year.[68] 2) Rather than limit these maps to a representation of the data pertaining to the origin of malting barley received at the four major markets, it was deemed advisable, since only 2 months were being considered, to include the smaller shipments received at the more important secondary terminals such as Omaha, Detroit, Toledo, and Buffalo.

A comparison of Figure 6 with the four maps shown in Figures 2-5 supports the belief that a representation of the points of origin of malting barley received during the two months August and September may be assumed to portray fairly the patterns developed in the crop-shipping year as a whole. It will be noted that all of the major areas revealed in the maps prepared from full or approximately full year data (1939-1940) for the four leading terminals are clearly defined in these maps showing only the two months of that year. The only previously designated area not appearing in Figure 6, is the one in northeastern Illinois which contributes to the Chicago market. The fact that this area is not represented on this map, or on the maps in Figures 7 and 8, results from an unfortunate method of data preparation at the Chicago market which did not permit an analysis of the records for these two months for this area. There is ample evidence to indicate that a large percentage of the total volume of shipments shown for this area in Figure 5 was moved in the August-September period.

For the purpose of visualizing the year-by-year differences in the actual production of the several potential areas, Figure 6 provides an excellent base of reference for a comparative examination of the records of earlier seasons. The outstanding *potential* areas, which in any year may be capable of producing large quantities of high-quality barley, may be listed from east to west as follows: 1) east-central Michigan; 2) northeastern Illinois; 3)

[68] M. J. Johnson, in conference with the author, May, 1940.

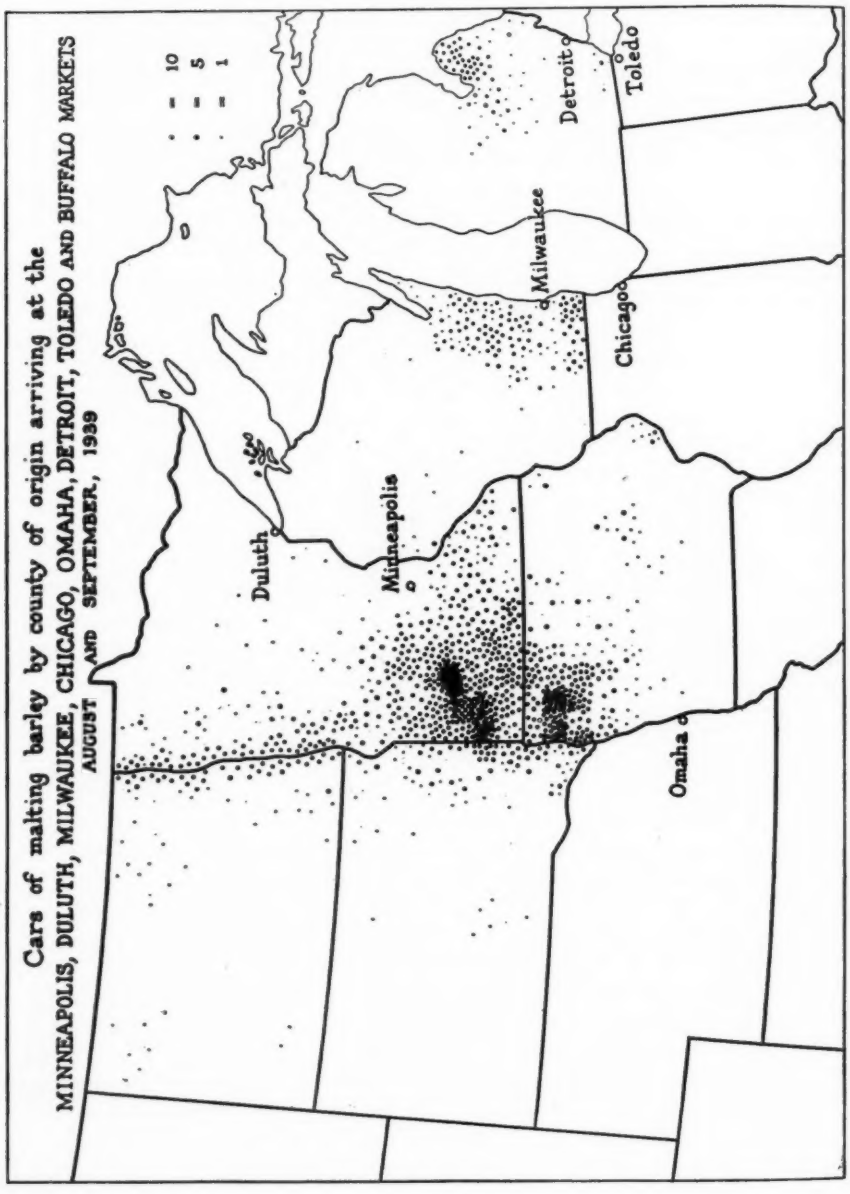
Cars of malting barley by county of origin arriving at the
MINNEAPOLIS, DULUTH, MILWAUKEE, CHICAGO, OMAHA, DETROIT, TOLEDO AND BUFFALO MARKETS
AUGUST AND SEPTEMBER, 1939
• = 10
• = 5
• = 1
Duluth
Minneapolis
Milwaukee
Chicago
Detroit
Toledo
Omaha

FIG. 6

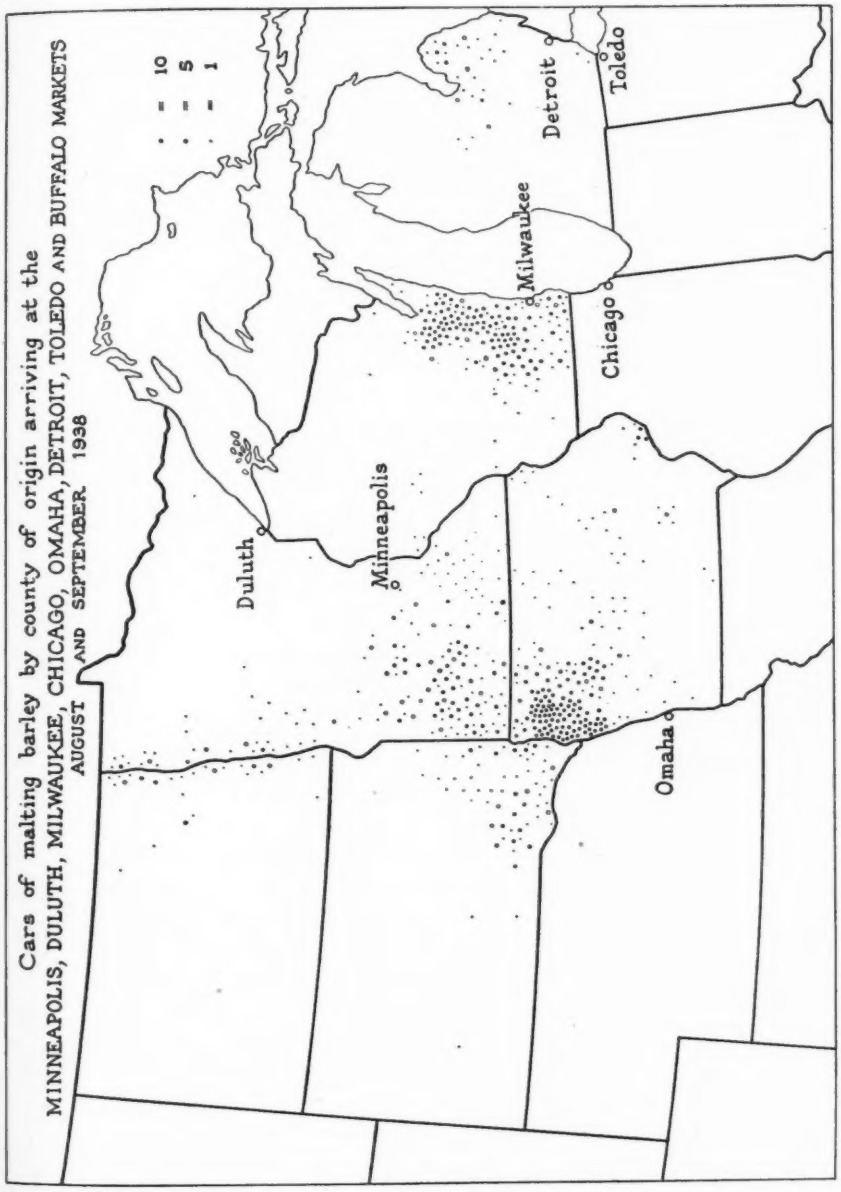
Cars of malting barley by county of origin arriving at the
MINNEAPOLIS, DULUTH, MILWAUKEE, CHICAGO, OMAHA, DETROIT, TOLEDO AND BUFFALO MARKETS
AUGUST AND SEPTEMBER 1938
. = 10
. = 5
. = 1
Duluth
Minneapolis
Milwaukee
Chicago
Detroit
Toledo
Omaha

FIG. 7

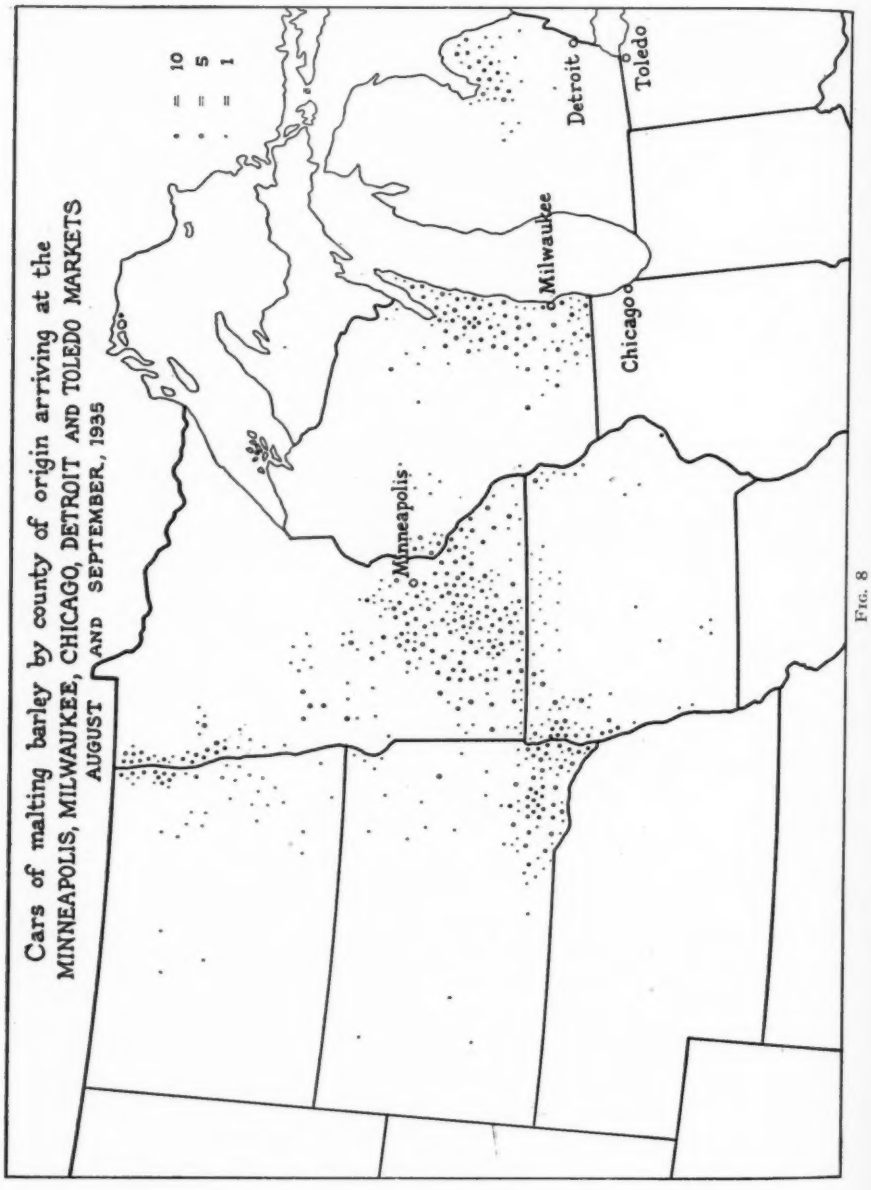
Cars of malting barley by county of origin arriving at the
MINNEAPOLIS, MILWAUKEE, CHICAGO, DETROIT AND TOLEDO MARKETS
AUGUST AND SEPTEMBER, 1935
• = 10
• = 5
• = 1
Minneapolis
Milwaukee
Chicago
Detroit
Toledo

FIG. 8

eastern Wisconsin; 4) southeastern Minnesota; 5) south-central and southwestern Minnesota and adjacent portions of east-central South Dakota; 6) northwestern Iowa and adjacent counties in southeastern South Dakota; and 7) the Red River Valley of northwestern Minnesota and eastern North Dakota. The position of these areal potentials provides a basis for the interpretative understanding of the comparable monthly shipments in the two earlier years of 1938 and 1935 (Figures 7 and 8).

In contrast to 1939, the year 1938 was considered to be an abnormal year in the production of malting barley.[69] As Figure 7 clearly indicates, the abnormality of the year was characterized by a strongly curtailed production in several of the *potential* areas. The eastern Wisconsin area, near the heart of the climatically defined North Central States region, maintained a strong production of grain suitable for malting. All of the somewhat more peripheral areas, however, with the notable exception of northwestern Iowa, contributed much reduced quantities of malting grain. The most severe failures occurred in the three major *potential* areas in Minnesota. Extensive storm damage, which "completely wiped out many choice fields," coupled with devastating attacks of blight, were responsible for the very substantial losses across the southern part of the state.[70] Although this season was said to have been a fairly satisfactory one in the Red River Valley,[71] it is clear that the market contributions of malting barley from that area were far below average. It will be noted that on the opposite, or eastern, periphery of the north-central region, in east-central Michigan, production was also seriously curtailed in this season.

In Figure 8, showing the points of origin of malting barley in 1935, still another pattern of emphasis appears among the *potential* areas. In that year, strong production appeared in south-central and southeastern Minnesota, in the northern Red River Valley, in a somewhat more extended than normal portion of southeastern South Dakota, and in east-central Michigan. In the lower Red River Valley, southwestern Minnesota, and northwestern Iowa, a severe blight epidemic resulted in greatly reduced shipments.[72] Outstanding for its consistent performance, the only area within the north-central region capable of high-quality production on a wide scale in all three of the years examined, was eastern Wisconsin.

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[69] M. J. Johnson, in conference with the author, May, 1940.

[70] Brookins: *Quality Prod. of Barley, op. cit.*, p. 7.

[71] Brookins: *Profits from Malting Barley, op. cit.*, p. 2.

[72] Brookins: *Quality Prod. of Barley, op. cit.*, p. 7.

Memoir of Arthur Keith

S. S. VISHER

Arthur Keith was a profound student of the Appalachians, especially of their structure and development, and made important contributions to an understanding of the shape and relief features of the entire North American continent. He was recognized as one of the most able and productive geologists. He was president of the Geological Society of America (1927) and was elected to the National Academy of Sciences (1928). He was connected with the United States Geological Survey from 1887 until his retirement at age 70 in 1934. He was elected to the Association of American Geographers in 1919 and maintained his membership until the end of his life.

Mr. Keith was born in St. Louis, Missouri, September 30, 1864, of Puritan stock. (His mother was the first woman to graduate from a college west of the Appalachians.) At Harvard he was a prominent athlete, a member of wrestling, football, and crew teams, and he long continued to be exceptionally active physically. He graduated in 1885 and took graduate work in 1885–1887. He died February 7, 1944, in his eightieth year. His wife died about two years earlier. They had no children.

Mr. Keith participated in various scientific organizations: For several years he was treasurer of the National Academy of Sciences; president (1914) of the Geological Society of Washington; vice president (1915) of the Washington Academy of Sciences; a member of the finance committee of the American Association for the Advancement of Science (1934–1939); chairman of the division of Geology and Geography of the National Research Council (1928–31). Other organizations with which he was affiliated were the American Association of Petroleum Geologists, American Institute of Mining Engineers, Seismological Society of America, and American Geophysical Union.

Mr. Keith was the author or co-author of several federal geologic folios and of bulletins on various mineral deposits in the Appalachians (iron ore, marbles, zinc, tin, talc). He also contributed to Professional Paper 70, on the Bingham District of Utah. New England glacial moraines also received some of his attention. Two especially noteworthy among his papers were "Outlines of Appalachian Structure," *Bull. Geol. Soc. Am.*, 34 (1923), 309–380, and "Structural Symmetry in North America," *ibid.*, 39 (1928), 321–385 (his presidential address). Some of his conclusions were that North America sustained major thrusts from all sides, three times

since the Cambrian, but that in basal shape and size it changed little throughout that long period. The sediments which accumulated in great troughs near the continent's margins were thrust inland to form mountain ranges near the coast. Following each thrust were long periods of quiet during which erosion removed most of the mountains.

Mr. Keith was a cultured, scholarly, kindly man who encouraged and stimulated quite a number of men who were fortunate enough to have contact with him. (The present writer had that good fortune during 1920–1921.) With his passing, few of the distinguished students and co-workers of the Association's founder, W. M. Davis, remain in the Association. Mr. Keith's contributions to Geography were chiefly to paleogeography and to a better understanding of relief features and mineral distribution.